FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol. 21, Nº 3, Special Issue, 2023, pp. 387 - 403
https://doi.org/10.22190/FUME230824036R

Original scientific paper

APPLICATION OF HYBRID DIBR-FUCOM-LMAW-BONFERRONI-GREY-EDAS MODEL IN MULTICRITERIA DECISION-MAKING

Marko Radovanović[1], Darko Božanić[1], Duško Tešić[1], Adis Puška[2], Ibrahim M. Hezam[3], Chiranjibe Jana[4]

[1]Military Academy, University of Defence in Belgrade, Belgrade, Serbia
[2]Department of Public Safety, Government of Brčko District of Bosnia and Herzegovina, Brčko, Bosnia and Herzegovina
[3]Statistics & Operations Research Department, College of Sciences, King Saud University, Riyadh, Saudi Arabia
[4]Department of Applied Mathematics with Oceanology and Computer Programming, Vidyasagar University, Midnapore, India

Abstract. *The selection of unmanned aerial vehicles for different purposes is a frequent topic of research. This paper presents a hybrid model of an unmanned aerial vehicle (UAV) selection using the Defining Interrelationships Between Ranked criteria (DIBR), Full Consistency Method (FUCOM), Logarithm Methodology of Additive Weights (LMAW) and grey - Evaluation based on Distance from Average Solution (G-EDAS) methods. The above-mentioned model is tested and confirmed in a case study. First of all, in the paper are defined the criteria conditioning the selection, and then with the help of experts and by applying the DIBR, FUCOM and LMAW methods, the weight coefficients of the criteria are determined. The final values of the weight coefficients are obtained by aggregating the values of the criteria weights from all the three methods using the Bonferroni aggregator. Ranking and selection of the optimal UAV from twenty-three defined alternatives is carried out using the G-EDAS method. Sensitivity analysis confirmed a high degree of consistency of the solutions obtained using other MCDM methods, as well as changing the criteria weight coefficients. The proposed model has proved to be stable; its application is also possible in other areas and it is a reliable tool for decision-makers during the selection process.*

Key words: *DIBR, FUCOM, LMAW, grey numbers, EDAS, unmanned aerial vehicle (UAV)*

Received: August 24, 2023 / Accepted October 08, 2023

Corresponding author: Darko Božanić
Military Academy, University of Defence in Belgrade, Veljka Lukica Kurjaka 33, 11040, Belgrade, Serbia
E-mail: darko.bozanic@va.mod.gov.rs

1. INTRODUCTION

Various UAVs are being used increasingly in various areas of human activity, both in civil and military sectors. Successful planning, organization and execution of modern military operations are based on information about the enemy, time and space, which can be collected using various systems, including UAVs. The global demand for UAVs is on the rise, as they are becoming increasingly crucial in enhancing the operational effectiveness of military units, positioning them as a vital component within combat systems [1]. Diverse possibilities lay the foundation for their utilization across various conditions and operational contexts. The possibilities of using UAV in combat operations are diverse: mine detection, electronic reconnaissance, electronic countermeasures, hyperspectral scanning, laser target marking, radar imaging, radar jamming, use as combat stations and anti-drone systems, management and leadership of units on the battlefield in the operation zone, as logistics stations, as transport support, as support for medical teams, etc.

An UAV is characterized as an aerial vehicle equipped with an engine, which is either operated remotely by a controller or possesses a certain level of autonomous capability, the use of which is one-time or possiblly can be used multiple times and can carry different types of cargo. They differ in terms of purpose, construction characteristics and the source of energy used to propel them. The UAV are often called drones and and if these are used for combat then are called Unmanned Combat Air Vehicle (UCAV). Various possibilities of UAVs application make a significant contribution to defence and security, but these are also used in agriculture [2], building, transportation [3], commerce, transmission, research [4], medicine [5,6], science, architecture, archeology [7], visual recording and imaging [8,9], photogramemetry [10], geology and forestry [11], fire fighting [12], mining, oceanography and meteorology [13]], environmental management, sports [14], mapping [15], etc. It is also possible to use them for recording, photography [16], monitoring [17], reconnaissance [18], detection [19], transport of various types of cargo [20], protection of important persons and objects, *etc*. The mentioned functions are significant and objective features for the implementation of unmanned aerial vehicles in various military units [21], because their utilization, there is a notable enhancement in the combat capabilities of units throughout the planning, arrangement, and execution of various military maneuvers. By selecting the optimal combat UAV and equipping army units, four very important capabilities would be significantly improved and these are the abilities to: command and lead, use the information space, efficiently deploy forces and be mobile in the area of operation. For the purpose of such selection, the multi-criteria DIBR-FUCOM-LMWA-Bonferonni-grey EDAS model is used.

Up to now, a plethora of MCDM techniques have been formulated to assist in making specific decisions [22–25]. The very application of MCDM methods to the problem of selecting the optimal UAV and the general application of these methods related to UAVs have been analyzed by numerous authors in their research. Therefore, Ali Karimoddini [26] selects the UAV and evaluates its performances in order to support bridge inspection using the AHP method. By applying hybrid model Interval Type-2 Fuzzy AHP and TOPSIS, it is analyzed the selection of MALE (Medium-Altitude Long-Endurance) UAV [27]. Radovanović et al. [28] examine the selection of UAV's serving to the requirements of tactical army units through the application of a hybrid fuzzy AHP-VIKOR model. Hamurcu and Eren [29] perform the selection of an UAV with MCDM model AHP- TOPSIS for army needs. Using fuzzy ANP method, Liu and Chan [30] analyze the importance of service quality indicators for drone-based imaging and photography. Karaşan and Kaya [31] employ the TOPSIS method to identify the optimal technology for controlling unmanned aerial vehicles in terms of efficiency.

The application of UAVs in research related to the military sphere is presented in certain publications. Milić et al. [18] investigate the utilization of UAVs in particular types of operations. Adamski [32] investigates the use of UAVs in modern conflicts. Petrovski and Radovanović [15] examine the integration of UAVs with command and information systems. Jović [33] scrutinizes the application of UAVs within counter-terrorism operations. Petrovski et al. [34] show the use of UAVs supported by mobile applications in crisis management.

According to the performed analysis, it can be concluded that the topic of an UAV/UCAV selection has been discussed in the literature so far, but there is room to approach the selection/ranking issue in a different way, respectively, by applying new MCDM methods. The contribution of this paper is combined. The primary importance of this paper lies in the definition of criteria important for the selection of the optimal UCAV. Another, no less important contribution is the improvement of the selection methodology, that is, the formation of a decision-making model drawing upon various MCDM techniques.

Apart from the introductory section, the paper comprises additional five sections. In the second section it is made a brief description of the model, respectively, the applied methods. Through the third section, the definition and calculation of the weight coefficients of the criteria and the ranking of alternative solutions are performed, that is, the application of the model is presented. The fourth section addresses sensitivity analysis, while in the fifth section is conducted comparative examination of the outcomes in relation to alternative MCDM approaches. At the end of the paper, the conclusion of this research is provided.

2. Model Description

The complexity of the research issue required the application of a hybrid model of MCDM, which is formed of the methods DIBR, FUCOM and LMAW for defining weight coefficients of criteria, as well as G-EDAS method for selecting the most favorable combat unmanned aerial vehicle, based on defined criteria, which is presented in the Fig. 1.

The first phase of the model includes the definition of criteria and the calculation of their weights using the DIBR, FUCOM and LMWA methods, and in the second phase, the aggregation of the weight coefficients of criteria is carried out using the Bonferroni aggregator. In the third phase, the alternatives are defined and the initial decision-making matrix, after which the most favorable solution is selected using the G-EDAS method. The fourth phase presents the sensitivity analysis, while in the fifth phase of the model a comparison of the results with other methods is performed. In the following sections it is provided a brief description of the methods used.

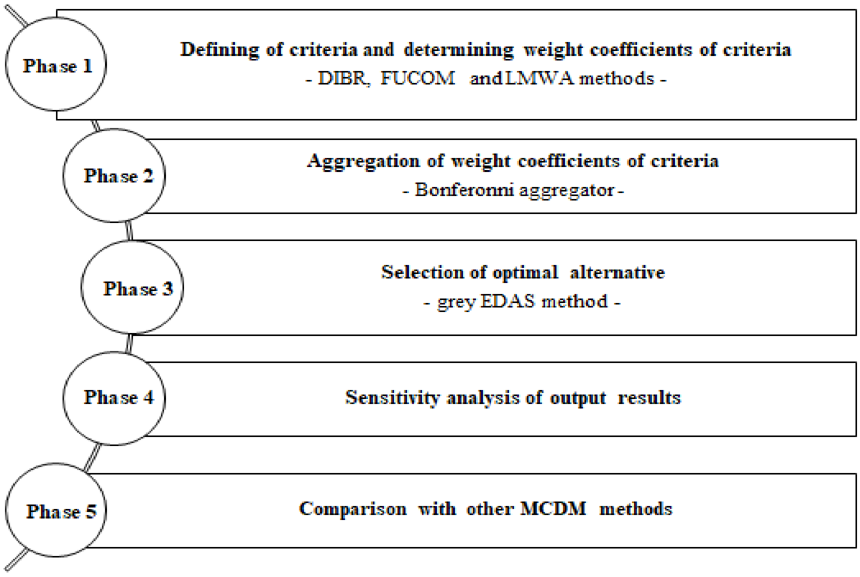

Fig. 1 DIBR-FUCOM-LMAW-Bonferonni-grey EDAS model

2.1. DIBR method

The DIBR method facilitates enhanced comprehension for decision makers regarding criteria relations by focusing solely on the connections between adjacent criteria [35]. This notably streamlines the process of deriving weight coefficients, especially in scenarios involving a substantial number of criteria. In general, with some methods that have found wide application in practice such as the AHP, in cases with an extensive array of criteria, upholding result consistency becomes more challenging; thus, this method employs a tree structure encompassing both main criteria and sub-criteria [36].

This method is still relatively underused in a significant part of the literature. Tešić et al. [37] use this method with the fuzzy MARCOS method for the selection of a location for overcoming obstacles. In the paper [38] is shown the combination of Fuzzy DIBR and Fuzzy-Rough EDAS methods. Lukić [39] used DIBR - WASPAS model to rank trading companies. The steps of the DIBR method are presented on the Fig. 2.

2.2. FUCOM method

The FUCOM method is one of the newer methods. It was applied for the first in the MCMD model in 2018 in the paper [40]. The FUCOM method (in basic or modifed version) is used in decision-making in combination with many other methods. Popović *et al*. [41] use gray FUCOM-SWOT model. Biswas et al. [42] use a fuzzy fermatean FUCOM-CODAS in the selection of a smartphone. Feizi et al. [43] present the FUCOM-MOORA and FUCOM MOOSRA model. Kahn et al. [44] present a novel fuzzy FUCOM-QFD approach. Pamučar et al. [45] developed a MCDM model - fuzzy FUCOM-neutrosophic fuzzy MARCOS. Stević et al. [46] present the FUCOM-EDAS model in the transport. The steps of the FUCOM method are presented on the Fig. 3.

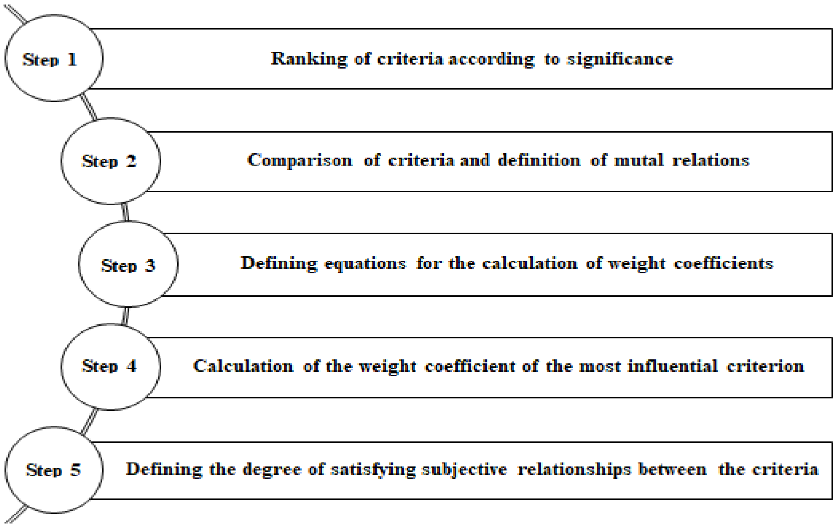

Fig. 2 Steps of the DIBR method [35]

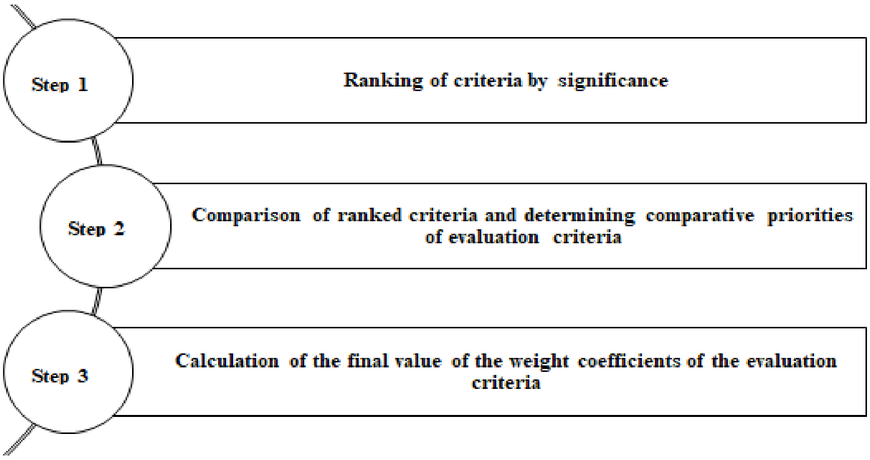

Fig. 3 Steps of the FUCOM method [40]

2.3. LMAW method

The LMAW method can be applied to determine weight coefficients of criteria and to select the optimal alternatives from a set of offered ones. It was developed in the paper by Pamučar et al. [47]. It is applied in many fields to solve various research issues. Until now, the LMAW method has been used in basic and modified form [48-51]. On Fig. 4 are presented the steps of the LMAW method related only to defining weight coefficients of criteria.

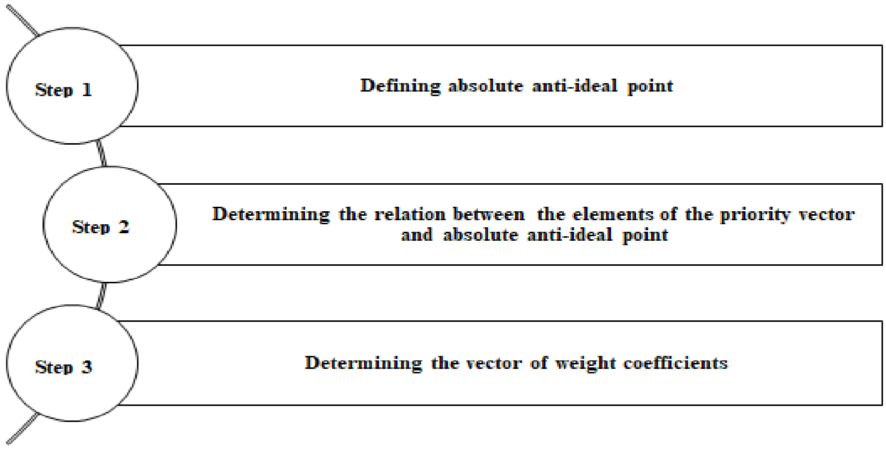

Fig. 4 Steps of the LMAW method related to calculation of weight coefficients of criteria [47]

2.4. Basics of the Grey Theory

The theory of grey numbers serves as a potent approach for addressing challenges involving partially known information. Represented by $\otimes x$, a grey number denotes a value whose precise magnitude is not known, yet its belonging range is established. When upper $\bar{x}$ and lower $\underline{x}$ bounds are known, but specifics about the distribution for x' are uncertain, it's referred to as an interval grey number [52].

$$\otimes x = [\underline{x}, \overline{x}] = [x' \in x | \underline{x} \leq x' \leq \overline{x}] \tag{1}$$

The degree of greyness presents the distance between their limits $\overline{x} - \underline{x}$. Depending of the degree of greyness interval number can become black number, white number or white (crisp) number. Further are presented the basic operations of interval grey numbers [53]:

$$\otimes x_1 + \otimes x_2 = [\underline{x_1} + \underline{x_2}, \overline{x}_1 + \overline{x}_2] \tag{2}$$

$$\otimes x_1 - \otimes x_2 = [\underline{x_1} - \overline{x}_2, \overline{x}_1 - \underline{x_2}] \tag{3}$$

$$\otimes x_1 \times \otimes x_2 = [\underline{x_1}\underline{x_2}, \overline{x}_1\overline{x}_2] \tag{4}$$

$$\otimes x_1 \div \otimes x_2 = \left[\frac{\underline{x_1}}{\overline{x}_2}, \frac{\overline{x}_1}{\underline{x_2}}\right] \tag{5}$$

$$e\otimes x_1 = e\otimes[\underline{x_1}, \overline{x}_1] = [e\underline{x_1}, e\overline{x}_1] \tag{6}$$

To determine the crisp (whitened) value $x_{(\delta)}$ for the interval grey number ($\otimes x = [\underline{x}, \overline{x}]$), the following expression is to be applied [48]:

$$x_{(\delta)} = (1 - \delta)\, \underline{x} + \delta\overline{x} \tag{7}$$

where $\delta \in [0,1]$ and present the whitening coefficient.

2.5. Grey EDAS method

The EDAS method was presented by Keshavarz Ghorabaee et al. [54]. The method has so far been applied in its basic form [55,56], as well as in fuzzy environment [57-62], grey environment [63,64] and rough environment [65]. The Fig. 5 shows the general steps of the G-EDAS method.

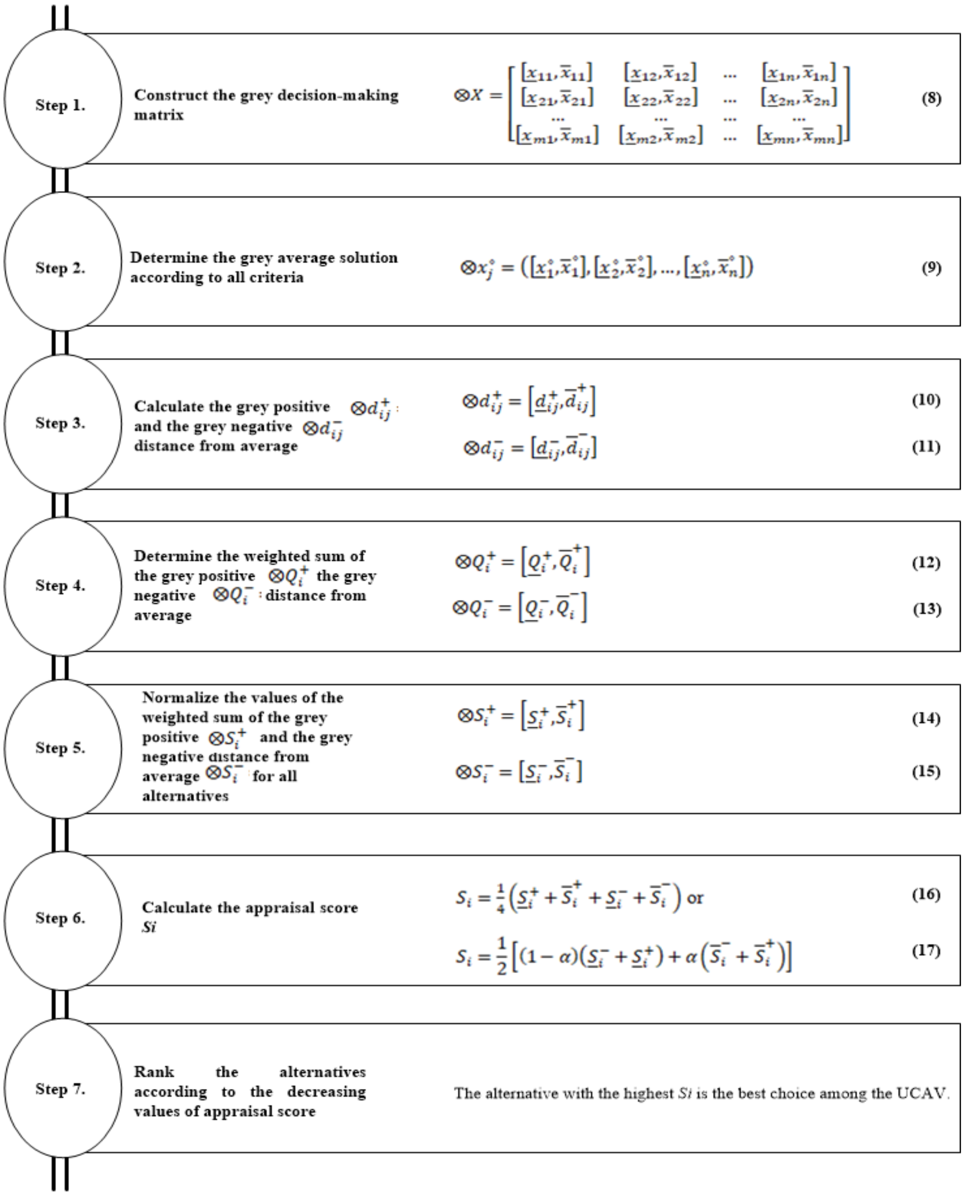

Fig. 5 General steps of the grey EDAS method [64]

3. Defining the Criteria and Application of the MCDM Model

A large number of unmanned aerial vehicles with different characteristics and applications can be found on the market. The military requirements for optimal unmanned aerial vehicles for use in various operations are non-uniform in terms of their tactical, technical and economic characteristics. On the basis of the above, it is defined the goal of selecting the optimal solution (unmanned aerial vehicle) which would best meet the needs of the armed forces in terms of its tactical, technical and economic characteristics. The solution obtained by this research can be used in equipping army units with unmanned aerial vehicles.

In the first phase of the application of the MCDM model are defined the criteria influencing the selection of the best UCAVs, for the needs of the army's tactical units. The establishment of criteria is rooted in the examination of the existing literature and the insights provided by subject matter experts (Table 1).

Table 1 Criteria determining the selection of UCAVs

Criterion	Name of the Criterion	Type of criteria	Unit of measure
C1	Flight autonomy	Benefit	hours (h)
C2	Maximum flight range	Benefit	kilometers (km)
C3	Weapon features of UCAV	Benefit	Linguistic
C4	Reliability	Benefit	Linguistic
C5	Maximum mass of the payload	Benefit	Linguistic
C6	Proce of one UCAV	Cost	US dollars ($)
C7	Maximum flight height	Benefit	meters (m)
C8	Maximum speed	Benefit	km/h

For the linguistic-type criteria it is used the scale presented in the Table 2.

Table 2 The scale for attribute evaluations $\otimes \boldsymbol{A}$ [66]

Scale	$\otimes A$
Very poor (VP)	[0,1]
Poor (P)	[1,3]
Medium poor (MP)	[3,4]
Fair (F)	[4,5]
Medium good (MG)	[5,6]
Good (G)	[6,9]
Very good (VG)	[9,10]

Based on the mentioned criteria, six experts defined the comparison values according to all the methods (DIBR, FUCOM, LMAW), after which the experts' viewpoints were consolidated using the Bonferroni aggregation method [67]:

$$BM^{r,s}(x_1, x_2 \dots, x_n) = \left(\frac{1}{n(n-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{n} x_i^r x_j^s\right)^{\frac{1}{r+s}} \quad (18)$$

Once the criteria have been established, in the initial phase are calculated their weight coefficients using the DIBR approach. Implementing the DIBR method's procedures, weight coefficients are computed individually for each of the six experts (Table 3). In Table 3 are further presented the aggregated values of criteria weight coefficients.

Table 3 Values of the weight coefficients of the criteria - DIBR method

Criteria	E1	E2	E3	E4	E5	E6	Aggregated values
C1	0.199	0.215	0.229	0.221	0.232	0.273	0.228
C2	0.163	0.169	0.173	0.182	0.174	0.181	0.174
C3	0.151	0.150	0.141	0.155	0.143	0.131	0.145
C4	0.128	0.113	0.111	0.117	0.112	0.103	0.114
C5	0.097	0.096	0.091	0.092	0.096	0.084	0.093
C6	0.082	0.079	0.077	0.075	0.081	0.072	0.078
C7	0.067	0.067	0.066	0.061	0.064	0.059	0.064
C8	0.060	0.057	0.058	0.052	0.052	0.052	0.055
C9	0.053	0.054	0.054	0.045	0.046	0.045	0.049

Using the FUCOM method, the results of the weight coefficients of the criteria are obtained and presented in the Table 4. The table 4 also shows the aggregated weight coefficients.

Table 4 Values of the weight coefficients of the criteria - FUCOM method

Criteria	E1	E2	E3	E4	E5	E6	Aggregated values
C1	0.217	0.239	0.194	0.225	0.196	0.237	0.218
C2	0.168	0.159	0.151	0.150	0.168	0.140	0.156
C3	0.145	0.120	0.109	0.114	0.130	0.119	0.123
C4	0.108	0.109	0.123	0.108	0.117	0.103	0.111
C5	0.094	0.092	0.104	0.100	0.098	0.095	0.097
C6	0.080	0.080	0.091	0.090	0.087	0.085	0.086
C7	0.072	0.073	0.082	0.077	0.078	0.079	0.077
C8	0.062	0.068	0.078	0.073	0.067	0.074	0.070
C9	0.054	0.060	0.068	0.063	0.059	0.068	0.062

Using the LMAW method, the results of the weight coefficients of the criteria are obtained and presented in the Table 5. The table 5 also shows the aggregated weight coefficients.

Table 5 Values of weight coefficients of criteria - LMAW method

Criteria	E1	E2	E3	E4	E5	E6	Aggregated values
C1	0.141	0.143	0.130	0.142	0.127	0.149	0.139
C2	0.134	0.137	0.136	0.128	0.133	0.142	0.135
C3	0.134	0.130	0.129	0.136	0.120	0.126	0.129
C4	0.127	0.129	0.123	0.120	0.127	0.135	0.127
C5	0.119	0.121	0.115	0.111	0.112	0.116	0.116
C6	0.109	0.111	0.115	0.111	0.093	0.126	0.111
C7	0.109	0.100	0.106	0.099	0.104	0.090	0.101
C8	0.085	0.086	0.106	0.086	0.104	0.071	0.090
C9	0.042	0.043	0.040	0.067	0.080	0.045	0.052

The final criteria weight coefficients result from the aggregation of the criteria weight coefficients derived through the DIBR, FUCOM, and LMAW approaches, as illustrated in the Table 6.

Table 6 Final values of the weight coefficients of the criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
Weight	0.194	0.155	0.133	0.118	0.103	0.092	0.080	0.071	0.054

Upon the establishing of the final weight coefficient values of the criteria, the process of selecting the optimal alternative from the set of potential ones is done using the G-EDAS technique. Six experts also participated in the evaluation of the alternatives. Aggregation of experts' opinions is carried out using the expression [66]:

$$\otimes x_j = \frac{1}{E}\left(\otimes x_j{}^1 + \otimes x_j{}^2 + \cdots + \otimes x_j{}^E\right) \tag{19}$$

where E presents the total number of experts.

The initial phase in implementing this approach involves formulating the initial decision matrix, as presented in the Table 7. The values in the table present the aggregated values of the evaluations of all alternatives according to all criteria by each of the experts, obtained by applying the expression (19).

Table 7 Initial decision-making matrix

	C1		C2		C3		...	C7		C8		C9	
	l1	u1	l2	u2	l3	u3	...	l7	u7	l8	u8	l9	u9
A1	27	40	200	300	5.50	7.50	...	5500	7620	185	220	6.500	9.167
A2	30	42	300	500	6.83	8.83	...	6000	8530	250	300	8.000	9.667
A3	20	28	1500	1852	4.00	5.00	...	12000	15240	400	482	6.333	8.667
A4	40	46	900	1100	3.00	4.17	...	6000	7620	180	217	4.000	5.000
…	…	…	…	…	…	…	...	…	…	…	…	…	…
A20	52	60	750	1000	7.00	9.33	...	7500	10000	250	280	3.333	4.333
A21	33	40	6000	7400	7.83	9.17	...	10000	14000	350	407	4.500	5.500
A22	32	39	750	1000	6.17	8.17	...	7500	9900	330	370	7.500	9.500
A23	40	46	20000	22800	4.50	5.50	...	15000	18000	550	629	6.500	9.167

After applying the steps of the G-EDAS method, the final ranking of the alternatives was obtained, table 8.

Table 8 Rank of the alternatives using the G-EDAS method

Alternatives	Φ_i	Ranking	Alternatives	Φ_i	Ranking
A1	0.346	15	A13	0.230	17
A2	0.403	11	A14	0.122	23
A3	0.516	7	A15	0.127	22
A4	0.379	12	A16	0.217	18
A5	0.590	3	A17	0.194	20
A6	0.308	16	A18	0.518	6
A7	0.567	5	A19	0.486	8
A8	0.581	4	A20	0.372	13
A9	0.361	14	A21	0.680	2
A10	0.164	21	A22	0.414	10
A11	0.207	19	A23	0.690	1
A12	0.477	9			

4. Sensitivity Analysis of the Model

Sensitivity analysis typically encompasses the observation of shifts in alternative rankings when modifications are applied to the weight coefficients of the criteria. [68-70]. Regarding the changing of criteria weight coefficients, various methodologies exist. In this study, a distinct criterion is highlighted in each scenario. The research outlines and presents ten scenarios involving changes to the weight coefficients of the criteria, as detailed in Table 9.

Table 9 Values of the weight coefficients of the criteria in relation to the scenario

Criteria	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
C1	0.194	0.111	0.304	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
C2	0.155	0.111	0.087	0.304	0.087	0.087	0.087	0.087	0.087	0.087	0.087
C3	0.133	0.111	0.087	0.087	0.304	0.087	0.087	0.087	0.087	0.087	0.087
C4	0.118	0.111	0.087	0.087	0.087	0.304	0.087	0.087	0.087	0.087	0.087
C5	0.103	0.111	0.087	0.087	0.087	0.087	0.304	0.087	0.087	0.087	0.087
C6	0.092	0.111	0.087	0.087	0.087	0.087	0.087	0.304	0.087	0.087	0.087
C7	0.08	0.111	0.087	0.087	0.087	0.087	0.087	0.087	0.304	0.087	0.087
C8	0.071	0.111	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.304	0.087
C9	0.054	0.112	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.304

The results obtained in relation to the defined scenarios are shown in the Fig. 6.

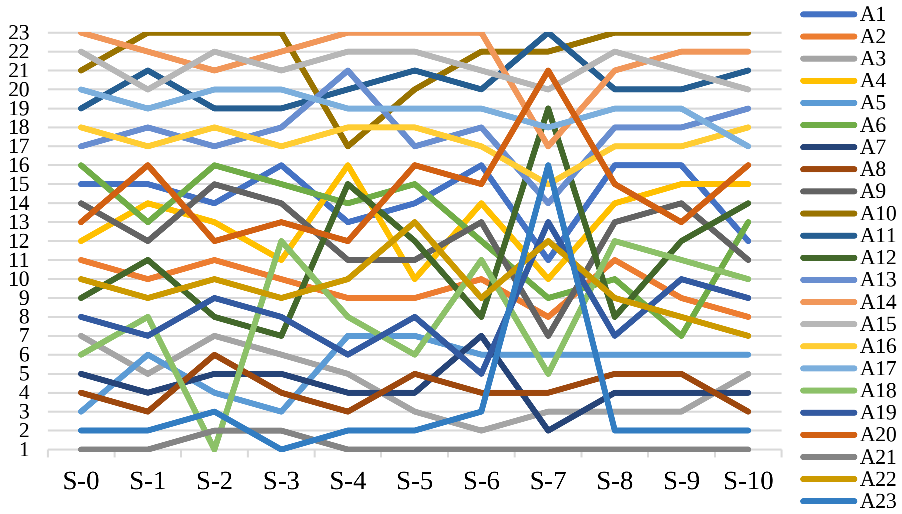

Fig. 6 Change in the ranks of alternatives depending on the change of the weight

In the Fig. 7 is displayed the Spearman's rank correlation coefficient for the changes in criteria weight coefficients concerning the initial ones. This figure reveals that across all scenarios, the outcomes consistently exhibit a trend towards a positive correlation, aligning closely with the ideal. Notably, the most pronounced deviation arises in the scenarios S7 to S10, wherein the priority is predominantly assigned to the criteria initially possessing lower weight coefficients. This particular trend indicates a logical disarray within the system.

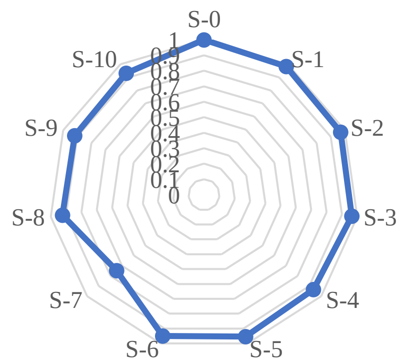

Fig. 7 The values of the Spearman’s coefficient of the rank correlations.

5. Comparative Analysis

In order to compare the obtained results with the results of other methods, the following methods are used: gray COPRAS [71], MABAC [72], ARAS [73], COCOSO [74], WASPAS [75], MAIRCA [76], gray TOPSIS [77], gray MARCOS [78] and gray OCRA [79,80]. In the Fig. 8 are shown the ranks of alternatives depending on the method used to select the optimal solution.

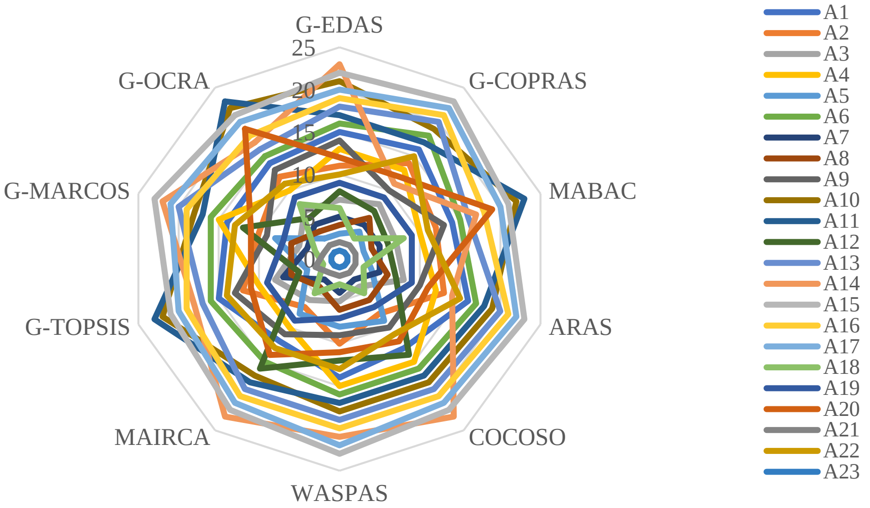

Fig. 8 Rank of alternatives depending on the MCDM model

Based on the results shown in the Fig. 8, it can be clearly observed that the alternative A23 has a high degree of stability, because it took the first position in applying ten different methods of MCDM, respectively, it presents the optimal solution. The alternative A21, the second on the ranking list, occupies the same position in 9 different methods, while in only one method it took the third place, which can be considered extremely stable rating.

6. Conclusion

The paper proposes a new hybrid MCDM model integrating the DIBR-FUCOM-LMAW methods, the results of which are aggregated using the Bonferroni aggregator with the grey EDAS method. The MCDM model is presented on the problem of selecting combat unmanned aerial vehicles that are in operational use by different armies of the world in order to equip tactical units of the Serbian Army. The DIBR, FUCOM and LMAW methods are used to determine the weight coefficients of the criteria, previously defined by experts and by analyzing available literature. By applying grey numbers integrated in the EDAS method, the best alternative is selected from a set of 23 different combat unmanned aerial vehicles. To validate the outcomes generated by the proposed model, a sensitivity analysis is conducted to assess the responsiveness of the output results to variations in criteria weight coefficients. Additionally, a comparison is made between the results obtained by the proposed model and those provided by other methods. The results stemming from this analysis and comparison collectively affirm the stability of the established model. One of the important limitations of the model is the fact that when defining the weight coefficients of the criteria, possible uncertainties are not considered, because the methods are applied in their basic form (with crisp values). Further research should be focused on the application of all presented methods in fuzzy and rough environment, as well as on solving other research issues.

Acknowledgment: *The fifth author, Ibrahim M. Hezam, was supported by "Research Supporting Project Number (RSP2023R389), King Saud University", Riyadh, Saudi Arabia.*

REFERENCES

1. Holder, A., 2020, *The centrality of militarised drone operators in militarised drone operations*, Ethnographic Studies, 17(1), pp. 81-99.
2. Özgüven, M.M., Altaş, Z., Güven, D., Çam, A., 2022, *Use of Drones in Agriculture and Its Future*, Ordu University Journal of Science and Technology, 12(1), pp. 64-83.
3. Mounica, B., Sathya, N., Likitha, R., Meghana, C.A., 2020, *Traffic Surveillance Using Smart Drone*, International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), 6(2), pp. 356-363.
4. Hall, O., Wahab, I., 2021, *The Use of Drones in the Spatial Social Sciences*, Drones, 5(4), 112.
5. Rosser, J.C.Jr, Vignesh, V., Terwilliger, B.A., Parker, B.C., 2018, *Surgical and Medical Applications of Drones: A Comprehensive Review*, Journal of The Society of Laparoscopic & Robotic Surgeons, 22(3), e2018.00018.
6. Gupta, K., Bansal, S., Goel, R., 2021, *Uses of Drones in Fighting COVID-19 Pandemic*, Proc. 10th International Conference on System Modeling & Advancement in Research Trends (SMART), Moradabad, India, pp. 651-655.
7. Campana, S., 2017, *Drones in Archaeology State-of-the-art and Future Perspectives*, Archaeological Prospection, 24(5), pp. 275-296.
8. Stankov, U., Kennell, J., Morrison, A.M., Vujičić, M., 2019, *The view from above: The relevance of shared aerial drone videos for destination marketing*, Journal of Travel & Tourism Marketing, 36(7), pp. 808-822.
9. Vázquez-Tarrío, D., Borgniet, L., Liébault, F., Recking, A., 2017, *Using UAS optical imagery and SfM photogrammetry to characterize the surface grain size of gravel bars in a braided river (Vénéon River, French Alps)*, Geomorphology, 285, pp. 94–105.
10. Piégay, H., Arnaud, F., Belletti, B., Bertrand, M., Bizzi, S., Carbonneau, P., Dufour, S., Liébault, F., Ruiz-Villanueva, V., Slater, L., 2020, *Remotely sensed rivers in the Anthropocene: State of the art and prospects.* Earth Surface Process and Landforms, 45(1), pp. 157-188.
11. Banu, T.P., Borlea, G.F., Banu, C., 2016, *The Use of Drones in Forestry*, Journal of Environmental Science and Engineering, B 5, pp. 557-562.
12. Cruz, H., Eckert, M., Meneses, J., Martínez, J.F., 2016, *Efficient Forest Fire Detection Index for Application in Unmanned Aerial Systems (UASs)*, Sensors, 16(6), 893.
13. Wieczorowski, M., Swojak, M., Pawlus, P., Pereira, A., 2021, *The Use of Drones in Modern Length and Angle Metrology*, Modern Technologies Enabling Safe and Secure UAV Operation in Urban Airspace, 59, pp. 125-140.
14. Nadobnik, J., 2016, *The use of drones in organizing the Olympic Games*, Handel Wewnętrzny, 6(365), pp. 288-299.
15. Petrovski, A., Radovanović, M., 2021, *Application of detection reconnaissance technologies use by drones in collaboration with C4IRS for military interested*, Contemporary Macedonian Defence, 21(40), pp. 117-126.
16. Padró, J.C., Muñoz, F.J., Ávila, L.Á., Pesquer, L., Pons, X., 2018, *Radiometric Correction of Landsat-8 and Sentinel-2A Scenes Using Drone Imagery in Synergy with Field Spectroradiometry*, Remote Sensing, 10(11), 1687.

17. Paneque-Gálvez, J., McCall, M.K., Napoletano, B.M., Wich, S.A., Koh, L.P., 2014, *Small Drones for Community-Based Forest Monitoring: An Assessment of Their Feasibility and Potential in Tropical Areas*, Forests, 5(6), pp. 1481-1507.
18. Milić, A., Ranđelović, A., Radovanović, M., 2019, *Use of drones in operations in the urban environment*, Proc. 5th International Scientific conference Safety and crisis management – Theory and practise Safety for the future (SecMan), Belgrade, Serbia, pp. 124-130.
19. Tanteri, L., Rossi, G., Tofani, V., Vannocci, P., Moretti, S., Casagli, N., 2017, *Multitemporal UAV Survey for Mass Movement Detection and Monitoring*. In: Mikos, M., Tiwari, B., Yin, Y., Sassa, K. (eds), Advancing Culture of Living with Landslides (WLF 2017), Springer, Cham, pp. 153-161.
20. Hassanalian, M., 2018, *Conceptual design, bioinspiration, and multidisciplinary analysis of drones*, PhD Thesis, New Mezico State University, Las Cruces, New Mezico, USA.
21. Krakowiak, E., 2018, *Unmanned Aerial Vehicles in the Security Service and as a New Tool in the Hands of Criminals*, Safety & Defense, 4(1), pp. 31-36.
22. Zheng, M., Teng, H., Wang, Y. 2023, *Application of new robust design by means of probability-based multi-objective optimization to machining process parameters*, Military Technical Courier, 71(1), pp. 84-99.
23. Yalcin, A.S., Kilic, S.H., Delen, D., 2022, *The use of multi-criteria decision-making methods in business analytics: A comprehensive literature review*, Technological Forecasting and Social Change, 174(15), 121193.
24. Narang, M., Kumar, A., Dhawan, R., 2023, *A fuzzy extension of MEREC method using parabolic measure and its applications*, Journal of Decision Analytics and Intelligent Computing, 3(1), pp. 33-46.
25. Granados, C., Das, A.K., Osu, B.O., 2023, *Weighted Neutrosophic Soft Multiset and Its Application to Decision Making*, Yugoslav Journal of Operations Research, 33(2), pp. 293-308,
26. Karimoddini, A., Cavalline, L.T., Smith, B., Hewlin, R., Homaifar, A., 2022, *UAV Selection Methodology and Performance Evaluation to Support UAV-Enabled Bridge Inspection*, Report Number: NCDOT2020-23NCDOT Project RP2020-23, Autonomous Cooperative Control of Emergent Systems of Systems (ACCESS) Laboratory Electrical and Computer Engineering Department North Carolina A&T State University.
27. Coban, S., Kiracı, K., Akan, E., Uzun, M., 2022, *MALE UAV selection in interval Type-2 fuzzy sets environment*, Journal of Intelligent and Fuzzy Systems, 43(5), pp. 1-28.
28. Radovanović M., Petrovski A., Žindrašič V., Ranđelović A., 2021, *Application of the fuzzy AHP -VIKOR hybrid model in the selection of an unmanned aircraft for the needs of tactical units of the armed forces*, Scientific Technical Review, 71(2), pp. 26-35.
29. Hamurcu, M., Eren, T., 2020, *Selection of Unmanned Aerial Vehicles by Using Multicriteria Decision-Making for Defence*, Journal of Mathematics, 2020(1), 4308756.
30. Liu, C.C., Chen, J.J., 2019, *Analysis of the Weights of Service Quality Indicators for Drone Filming and Photography by the Fuzzy Analytic Network Process*, Applied Sciences, 9(6), 1236.
31. Karaşan, A., Kaya, İ., 2020, *Neutrosophic TOPSIS Method for Technology Evaluation of Unmanned Aerial Vehicles (UAVs)*, Proc. Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making (INFUS 2019), Advances in Intelligent Systems and Computing, 1029, pp. 665-673.
32. Adamski, M., 2020, *Effectiveness analysis of UCAV used in modern military conflicts*, Aviation, 24(2), pp. 66-71.
33. Jović, Ž., 2016, *Combat engagement of drones in USA counterterrorist operations*, Bezbednost, 58(3), pp. 171-190.
34. Petrovski, A., Bogatinov, D., Radovanovic, M., Radovanovic, M., 2023, *Application of Drones in Crises Management Supported Mobile Applications and C4IRS Systems*, In: Dobrinkova, N., Nikolov, O. (eds), Environmental Protection and Disaster Risks (EnviroRISKs 2022), Lecture Notes in Networks and Systems, 638. Springer, Cham, pp. 321-334.
35. Pamucar, D., Deveci, M., Gokasar, I., Işık, M., Zizovic, M., 2021, *Circular economy concepts in urban mobility alternatives using integrated DIBR method and fuzzy Dombi CoCoSo model*, Journal of cleaner production, 323, 129096.
36. Alosta, A., Elmansuri, O., Badi, I., 2021, *Resolving a location selection problem by means of an integrated AHP-RAFSI approach*, Reports in Mechanical Engineering, 2(1), pp. 135-142.
37. Tešić, D., Božanić, D., Pamučar, D., Din, J., 2022, *DIBR–FUZZY MARCOS model for selecting a location for a heavy mechanized bridge*, Military Technical Courier, 70(2), pp. 314-339.
38. Pamucar, D., Simic, V., Lazarević, D., Dobrodolac, M., Deveci, M., 2022, *Prioritization of Sustainable Mobility Sharing Systems Using Integrated Fuzzy DIBR and Fuzzy-Rough EDAS Model*, Sustainable Cities and Society, 82, 103910.
39. Lukić, R., 2023, *Performance Analysis of Trading Companies in Serbia Based on DIBR - WASPAS Methods*, Proc. 28th International Scientific Conference Strategic Management and Decision Support Systems in Strategic Management SM 2023, Subotica, Serbia, pp. 361-372.

40. Pamučar, D., Stević, Ž., Sremac, S., 2018, *A New Model for Determining Weight Coefficients of Criteria in MCDM Models: Full Consistency Method (FUCOM),* Symmetry, 10(9), 393.
41. Popović, V., Pamučar, D., Stević, Ž., Lukovac, V., Jovković, S., 2022, *Multicriteria Optimization of Logistics Processes Using a Grey FUCOM-SWOT Model,* Symmetry, 14(4), 794.
42. Biswas, S., Pamučar, D., Kar, S., Sana, S.S., 2021, *A New Integrated FUCOM–CODAS Framework with Fermatean Fuzzy Information for Multi-Criteria Group Decision-Making*, Symmetry, 13(12), 2430.
43. Feizi, F., Karbalaei-Ramezanali, A.A., Farhadi, S., 2021, *FUCOM-MOORA and FUCOM-MOOSRA: new MCDM-based knowledge-driven procedures for mineral potential mapping in greenfields*, SN Applied Science, 3, 358.
44. Khan, F., Ali, Y., Pamucar, D., 2022, *A new fuzzy FUCOM-QFD approach for evaluating strategies to enhance the resilience of the healthcare sector to combat the COVID-19 pandemic*, Kybernetes, 51(4), pp. 1429-1451.
45. Pamučar, D., Ecer, F., Deveci., M., 2021, *Assessment of alternative fuel vehicles for sustainable road transportation of United States using integrated fuzzy FUCOM and neutrosophic fuzzy MARCOS methodology*, Science of The Total Environment, 788, 147763.
46. Stević, Ž., Pamučar, D., Sremac, S., 2019, *An Integrated FUCOM-EDAS Model for Decision Making in Transportation of Dangerous Goods,* Proc. 15th International May Conference on Strategic Management (IMCSM), Bor, Serbia, 15(1), pp. 17-25.
47. Pamučar, D., Žižović, M., Biswas, S., Božanić, D., 2021, *A new Logarithm Methodology of Additive Weights (LMAW) for Multi-Criteria Decision-Making: Application in Logistics,* Facta Universitatis Series: Mechanical Engineering, 19(3), pp. 361-380.
48. Tešić, D., Božanić, D., Puška, A., Milić, A., Marinković, D., 2023, *Development of the MCDM fuzzy LMAW-grey MARCOS model for selection of a dump truck*, Reports in Mechanical Engineering, 4(1), pp. 1-17.
49. Lukić, R., 2023, *Application of the LMAW-DNMA method in the evaluation of the environmental problem in the agriculture of selected European Union countries*, Acta Agriculturae Serbica, 28(55), 49-61.
50. Lukić, R., 2023, *Measurement and analysis of profitability dynamics of the banking sector in Serbia based on the FLMAW-MARCOS method*, Bankarstvo, 52(1), 8-47.
51. Sıcakyüz, Ç., 2023, *Analyzing Healthcare and Wellness Products' Quality Embedded in Online Customer Reviews: Assessment with a Hybrid Fuzzy LMAW and Fermatean Fuzzy WASPAS Method*, Sustainability, 15(4), 3428.
52. Lin, Y.H., Lee, P.C., Chang, T.P., Ting, H.I., 2008, *Multi-attribute group decision making model under the condition of uncertain information,* Automation in Construction, 17(6), pp. 792-797.
53. Deng, J.L., 1992, *An Introduction to Grey Mathematics–Grey Hazy Set*, Press of Huazhong University of Science and Technology, Wuhan.
54. Keshavarz Ghorabaee, M., Zavadskas, E.K., Olfat, L., Turskis, Z., 2015, *Multicriteria inventory classification using a new method of evaluation based on distance from average solution (EDAS),* Informatica, 26(3), pp. 435-451.
55. Ecer, F., 2018, *Third-party logistics (3Pls) provider selection via Fuzzy AHP and EDAS integrated model*, Technological and Economic Development of Economy, 24(2), pp. 615-634.
56. Komasi, H., Zolfani, S. H., Nemati, A., 2023, *Evaluation of the social-cultural competitiveness of cities based on sustainable development approach*, Decision Making: Applications in Management and Engineering, 6(1), 583-602.
57. Peng, Z., Dai, J., Yuan, H., 2017, *Interval-valued fuzzy soft decision-making methods based on MABAC, similarity measure and EDAS,* Fundamenta Informaticae, 152(4), pp. 373-396.
58. Keshavarz Ghorabaee, M., Amiri, M., Zavadskas, E.K., Turskis, Z., 2017, *Multi-criteria group decision-making using an extended EDAS method with interval type-2 fuzzy sets,* Ekonomika a management, 20(1), pp. 48-68.
59. Menekşe, A., Camgöz Akdağ, H., 2022, *Distance education tool selection using novel spherical fuzzy AHP EDAS,* Soft Computing, 26(4), pp. 1617-1635.
60. Karatop, B., Taskan, B., Adar, E., Kubat, C., 2021, *Decision analysis related to the renewable energy investments in Turkey based on a fuzzy AHP-EDAS-fuzzy FMEA approach*, Computers & Industrial Engineering, 151(3), 106958.
61. Kahraman, C., Keshavarz Ghorabaee, M., Zavadskas, E.K., Cevik Onar, S., Yazdani, M., Oztaysi, B., 2017, *Intuitionistic fuzzy EDAS method: an application to solid waste disposal site selection,* Journal of Environmental Engineering and Landscape Management, 25(1), pp. 1-12.
62. Liang, Y., 2020, *An EDAS method for multiple attribute group decision-making under intuitionistic fuzzy environment and its application for evaluating green building energy-saving design projects*, Symmetry, 12(3), 484.

63. Rogulj, K., Pamuković, J.K., Antucheviciene, J., Zavadskas, E.K., 2022, *Intuitionistic Fuzzy Decision Support Based on EDAS and Grey Relational Degree for Historic Bridges Reconstruction Priority*, Soft computing, PREPRINT (Version 1). Available at Research Square: https://doi.org/10.21203/rs.3.rs-1164217/v1.
64. Stanujkić, D., Zavadskas, E.K., Keshavarz Ghorabaee, M., Turskis, Z., 2017, *An Extension of the EDAS Method Based on the Use of Interval Grey Numbers*, Studies in Informatics and Control, 26(1), pp. 5-12.
65. Terzioglu, T., Polat, G., 2022, *Formwork System Selection in Building Construction Projects Using an Integrated Rough AHP-EDAS Approach: A Case Study*, Buildings, 12(8), 1084.
66. Li, G.D., Yamaguchi, D., Nagai, M., 2007, *A grey-based decision-making approach to the supplier selection problem*, Mathematical and Computer Modelling, 46(3-4), 573-581.
67. Bonferroni, C., 1950, *Sulle medie multiple di potenze*, Bollettino Matematica Italiana, 5(3-4), pp. 267-270.
68. Bošković, S., Švadlenka, L., Dobrodolac, M., Jovčić, S., Zanne, M., 2023, *An Extended AROMAN Method for Cargo Bike Delivery Concept Selection,* Decision Making Advances, 1(1), pp. 1-9.
69. Biswas, S., Joshi, N., 2023, *A Performance based Ranking of Initial Public Offerings (IPOs) in India*, Journal of Decision Analytics and Intelligent Computing, 3(1), pp. 15-32.
70. Đukić, Đ., Petrović, I., Božanić, D., Delibašić, B., 2022, *Selection of Unployed Aircraft for Training of Small-Range Aircraft Defense System AHP – TOPSIS Optimization Methods*, Yugoslav Journal of Operations Research, 32(3), pp. 389-406.
71. Roozbahani, A., Ghased, H., Hashemy, S.M., 2020, *Inter-basin water transfer planning with grey COPRAS and fuzzy COPRAS techniques: A case study in Iranian Central Plateau*, Science of The Total Environment, 726, 138499.
72. Pamučar, D., Ćirović, G., 2015, *The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC)*, Expert Systems with Applications, 42, pp. 3016-3028.
73. Zavadskas, E.K., Turskis, Z., 2010, *A new additive ratio assessment (ARAS) method in multicriteria decision-making*, Technological and Economic Development of Economy, 16(2), pp. 159-172.
74. Badi, I., Stević, Ž, Bayane Bouraima, M., 2023, *Overcoming Obstacles to Renewable Energy Development in Libya: An MCDM Approach towards Effective Strategy Formulation*, Decision Making Advances, 1(1), 17-24.
75. Zavadskas, E.K., Turskis, Z., Antucheviciene, J., Zakarevicius, A., 2012, *Optimization of Weighted Aggregated Sum Product Assessment*, Elektronika ir Elektrotechnika, 122(6), pp. 3-6.
76. Gigović, L., Pamučar, D., Bajić, Z., Milićević, M., 2016, *The Combination of Expert Judgment and GIS-MAIRCA Analysis for the Selection of Sites for Ammunition Depots*, Sustainability, 8(4), 372.
77. Sadeghi, M., Razavi, S.H., Saberi, N, 2013, *Application of Grey TOPSIS in Preference Ordering of Action Plans in Balanced Scorecard and Strategy Map*, Informatica, 24(4), pp. 619-635.
78. Bitarafan, M., Amini Hosseini, K., Zolfani, S.H., 2023, *Identification and assessment of man-made threats to cities using integrated Grey BWM- Grey MARCOS method*, Decision Making: Applications in Management and Engineering, 6(2), pp. 581-599.
79. 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.
80. Stanujkić, D., Zavadskas, E.K., Liu, S., Karabašević, D., Popović, G., 2017, *Improved OCRA Method Based on the Use of Interval Grey Numbers*, The Journal of Grey System, 29(4), pp. 49-60.