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Use of the DIBR-Grey EDAS Model of MCDM to the Selection of a Combat Unmanned Ground Platform

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ABSTRACT

The paper presents a hybrid model of choosing a combat unmanned ground platform using the DIBR and grey – EDAS (G-EDAS) method. This model has been tested and confirmed on a case study in which combat unmanned platforms for the needs of the military were optimized. The criteria were defined, and then the DIBR method was used to determine the severity of the criteria. The ranking and selection of the most favorable alternative (combat unmanned ground platform) was carried out using the G-EDAS method. An analysis of the sensitivity of the proposed model was performed depending on the change in the weighting coefficients of the criteria. The proposed model has proven to be stable and is a reliable tool for the decision maker when choosing.

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1. Introduction

Unmanned ground vehicles are now being used for both military and civilian purposes in various fields in our environment, particularly in industry and agriculture (Bonadies et al., 2016; Hu et al., 2023). Today, combat operations require the use of the most sophisticated combat systems to effectively achieve the goal. The use of unmanned aerial vehicles and unmanned ground vehicles is an indispensable segment of modern combat operations. They enable a wide range of uses and increase the efficiency of the units that use them. At the end of the 20th century, an unmanned automated mobile platform was rapidly developed, where the primacy consists of Unmanned Ground Vehicles (UGVs) designed to move around arranged or unregulated terrain (Gage, 1995; Szpaczyńska et al., 2022).

Unmanned ground platforms have a wide range of capabilities for use during combat operations of the army such as reconnaissance, raiding, detection and destruction of unexploded ordnance, evacuation of injured and sick, transport, providing fire support to forces in combat operations and others (Wei et al., 2017). Unmanned ground platforms should provide efficient and effective execution of tasks in combat operations without risk to manpower, by replacing soldiers in certain missions and thus providing security and security for soldiers in high-risk zones.

Combat operations use various types of combat ground best from crew platforms, among which unobstructed UGVs vehicles are leading the way, which transmit data from the battlefield to the command center and provide fire support to maneuvering units (Hurin and Matvieiev, 2023). There is an increasing use of various types of combat UGVs, especially for reconnaissance, detection, surveillance and targeting on the ground (Petrovski & Radovanović, 2021) . There are certain characteristics that need to be fulfilled in order for unmanned ground vehicles to be efficient and in combat and meet the conditions of modern warfare.

Unmanned ground vehicles continue to improve in terms of intelligence, mobility, and reliability. The U.S. military uses over 3,000 such vehicles. The tasks of these vehicles range from security, logistical support to detection and neutralization of explosive devices. The directions of development of unmanned terrestrial platforms go towards maximum system autonomy and the development of energy-sustainable solar-powered platforms.

The MCDM model is based on the application of DIBR and grey EDAS methods, whereby the determination of weight coefficients of criteria as one of the complex problems of research was carried out by the engagement of experts. One of the goals of the paper is to define criteria important for the selection of an optimal combat defenseless ground platform and to form a model that will achieve the goal, a scientifically based approach to choosing the most optimal alternative for the needs of the army (Radovanović et al., 2021). The second objective of the paper is to improve the methodology for determining the criteria for the selection and selection of the optimal combat unmanned ground platform, while the objective is to confirm the effectiveness of the DIBR- grey EDAS model.

2. Description of methods

Due to the specificity of the research problem, a hybrid model (Narang et al., 2023) composed of a combination of thee DIBR method and the G - EDAS method for selecting a landless platform based on the given criteria. The data used in the research was obtained based on available literature and content analysis. The described model is based on knowledge of DIBR and EDAS decision-making methods and grey numbers.

2.1. DIBR method

The DIBR method was first presented in the Pamučar et al. (2021). This method is based on defining the relationship between ranked criteria. Experts or decision-makers are obliged to rank the criteria and perform a mutual comparison of adjacent criteria. Further calculation is made possible by applying the mathematical apparatus of the DIBR method. The method can be used both in individual and group decision-making. The DIBR method allows decision-makers to better perceive the relationships between criteria, since it considers relationships between adjacent criteria. Using this method, decision makers have the opportunity to express their preferences more objectively (Pamučar et al., 2022)

The application of this method in its original or modified form has been used to solve various research problems, as shown in Table 1.

Table 1. Literatura review

References	Applied methods
Tešić et al. (2022a)	DIBR–FUZZY MARCOS
Tešić et al. (2022b)	Rough DIBR-Rough MABAC
Pamučar et al. (2022)	Fuzzy DIBR and Fuzzy-Rough EDAS
Lukić (2023)	DIBR - WASPAS
Radovanović et al. (2023)	DIBR-FUCOM-LMAW-Bonferroni-grey-EDAS
Tešić et al. (2023)	DIBR–DOMBI–FUZZY MAIRCA

Table 2 shows the steps of the DIBR method.

Table 2. Steps of the DIBR method

Step 1.	Ranking of criteria according to significance	$C_1 > C_2 > C_3 > \cdots > C_n$
Step 2.	Comparison of criteria and definition of mutal relations (w and λ)	$w_1 : w_2 = (1 - \lambda_{1,2}) : \lambda_{1,2}$ (1) $w_2 : w_3 = (1 - \lambda_{2,3}) : \lambda_{2,3}$ (2) … $w_{n-1} : w_n = (1 - \lambda_{n-1,n}) : \lambda_{n-1,n}$ (3) $w_1 : w_n = (1 - \lambda_{1,n}) : \lambda_{1,n}$ (4)
Step 3.	Defining equations for the calculation of weight coefficients (w)	$w_2 = \frac{\lambda_{1,2}}{(1\text{-}\lambda_{1,2})} w_1$ (5) $w_3 = \frac{\lambda_{2,3}}{(1-\lambda_{2,3})} w_2 = \frac{\lambda_{1,2}\lambda_{2,3}}{(1-\lambda_{1,2})(1-\lambda_{2,3})} w_1$ (6) … $w_n = \frac{\lambda_{1,n}}{(1-\lambda_{n-1,n})} w_{n-1} = \frac{\lambda_{1,2}\lambda_{2,3},\ldots,\lambda_{n-1,n}}{(1-\lambda_{1,2})(1-\lambda_{2,3}),\ldots,(1-\lambda_{n-1,n})} w_1 = \frac{\prod_{i=1}^{n-1}\lambda_{i,i+1}}{\prod_{i=1}^{n-1}(1-\lambda_{i,i+1})} w_1$ (7)
Step 4.	Calculation of the weight coefficient of the most influential criterion (w)	$w_1\left(1 + \frac{\lambda_{12}}{(1-\lambda_{12})} + \frac{\lambda_{12}\lambda_{23}}{(1-\lambda_{12})(1-\lambda_{23})} + \cdots + \frac{\prod_{i=1}^{n-1}\lambda_{i,i+1}}{\prod_{i=1}^{n-1}(1-\lambda_{i,i+1})}\right) = 1$ (8)
Step 5.	Defining the degree of satisfying subjective relationships between the criteria (w and λ)	$w_n = \frac{\lambda_{1,n}}{(1-\lambda_{1,n})} w_1$ (9) $\lambda_{1,n} = \frac{w_n}{w_1+w_n}$ (10)

2.2. Grey EDAS method

The EDAS approach was first submitted to the literature by Keshavarz Ghorabaee, et al. (2015) as a new MCDM method. Improvement of the EDAS with grey numbers method was done by Stanujkić et al. (2017). The basic ideas of the EDAS method are the use of two distance measures, namely the Positive and the Negative Distance from Average (PDA and NDA). A decision-making problem in which m alternatives are evaluated with n criteria, and where the characteristics of the alternatives are not exactly known, can be represented as a gray number, where the values of the gray number indicate the minimum and maximum expected performance ratings of the alternative in relation to the criteria..

The application of this method in its original or modified form has been used to address various research problems, as depicted in Table 3.

Table 3. Literatura review

References	Applied methods
Kahraman et al., (2017)	Fuzzy EDAS
Stanujkić et al. (2017)	Grey EDAS
Karasan and Kahraman, (2017)	EDAS
Peng et al., (2017)	Fuzzy MABAC-EDAS
Peng and Liu (2017)	EDAS
Ghorabaee et al., (2017)	Fuzzy EDAS
Stević et al., (2019)	Fuzzy AHP-EDAS
Ozcelik & Nalkiran, (2021)	Fuzzy EDAS
Zhang et al., (2023)	Fuzzy PT-EDAS
Menekse & Akdag, (2022)	spherical fuzzy AHP EDAS
Zhang et al., (2022)	WEPLPA-CPT-EDAS
Torkayesh et al., (2023)	EDAS

Then, the computational procedure of the proposed extension of the EDAS method can be expressed concisely though the following steps in Table 4 (Ulutaş, 2017).

Table 4. Steps of the grey EDAS method

Step 1.	Construct the grey decision-making matrix (X)	$\otimes X = \begin{bmatrix} [\underline{x}_{11}, \overline{x}_{11}] & [\underline{x}_{12}, \overline{x}_{12}] & \dots & [\underline{x}_{1n}, \overline{x}_{1n}] \\ [\underline{x}_{21}, \overline{x}_{21}] & [\underline{x}_{22}, \overline{x}_{22}] & \dots & [\underline{x}_{2n}, \overline{x}_{2n}] \\ \dots & \dots & \dots & \dots \\ [\underline{x}_{m1}, \overline{x}_{m1}] & [\underline{x}_{m2}, \overline{x}_{m2}] & \dots & [\underline{x}_{mn}, \overline{x}_{mn}] \end{bmatrix}$	(11)
Step 2.	Determine the grey average solution according to all criteria	$\otimes x_j^{\diamond} = \left([\underline{x}_1^{\diamond}, \overline{x}_1^{\diamond}], [\underline{x}_2^{\diamond}, \overline{x}_2^{\diamond}], \dots, [\underline{x}_n^{\diamond}, \overline{x}_n^{\diamond}]\right)$	(12)
Step 3.	Calculate the grey positive and the grey negative distance from average	$\underline{d}_{ij}^{+} = \begin{cases} \frac{\max\left(0, \left(\underline{x}_{ij} - \overline{x}_j^{\diamond}\right)\right)}{0.5\left(\underline{x}_j^{\diamond} + \overline{x}_j^{\diamond}\right)}; & j \in \Omega_{max} \\ \frac{\max\left(0, \left(\underline{x}_j^{\diamond} - \overline{x}_{ij}\right)\right)}{0.5\left(\underline{x}_j^{\diamond} + \overline{x}_j^{\diamond}\right)}; & j \in \Omega_{min} \end{cases}$ (13) $\overline{d}_{ij}^{+} = \begin{cases} \frac{\max\left(0, \left(\overline{x}_{ij} - \overline{x}_j^{\diamond}\right)\right)}{0.5\left(\underline{x}_j^{\diamond} + \overline{x}_j^{\diamond}\right)}; & j \in \Omega_{max} \\ \frac{\max\left(0, \left(\underline{x}_j^{\diamond} - \underline{x}_{ij}\right)\right)}{0.5\left(\underline{x}_j^{\diamond} + \overline{x}_j^{\diamond}\right)}; & j \in \Omega_{min} \end{cases}$ (14) $\underline{d}_{ij}^{-} = \begin{cases} \frac{\max\left(0, \left(\underline{x}_j^{\diamond} - \overline{x}_{ij}\right)\right)}{0.5\left(\underline{x}_j^{\diamond} + \overline{x}_j^{\diamond}\right)}; & j \in \Omega_{max} \\ \frac{\max\left(0, \left(\underline{x}_{ij} - \underline{x}_j^{\diamond}\right)\right)}{0.5\left(\underline{x}_j^{\diamond} + \overline{x}_j^{\diamond}\right)}; & j \in \Omega_{min} \end{cases}$ (15) $\overline{d}_{ij}^{-} = \begin{cases} \frac{\max\left(0, \left(\underline{x}_j^{\diamond} - \underline{x}_{ij}\right)\right)}{0.5\left(\underline{x}_j^{\diamond} + \overline{x}_j^{\diamond}\right)}; & j \in \Omega_{max} \\ \frac{\max\left(0, \left(\overline{x}_{ij} - \underline{x}_j^{\diamond}\right)\right)}{0.5\left(\underline{x}_j^{\diamond} + \overline{x}_j^{\diamond}\right)}; & j \in \Omega_{min} \end{cases}$ (16)	(13) (14) (15) (16)
Step 4.	Determine the weighted sum of the grey PDA and grey NDA	$\underline{Q}_i^{+} = \sum_{j=1}^{n} w_j \underline{d}_{ij}^{+},$ $\overline{Q}_i^{+} = \sum_{j=1}^{n} w_j \overline{d}_{ij}^{+},$ $\underline{Q}_i^{-} = \sum_{j=1}^{n} w_j \underline{d}_{ij}^{-},$ $\overline{Q}_i^{-} = \sum_{j=1}^{n} w_j \overline{d}_{ij}^{-}.$	(17) (18) (19) (20)
Step 5.	Normalize the values of the weighted sum of the grey PDA and the weighted sum of the grey NDA for all alternatives	$\underline{S}_i^{+} = \frac{\underline{Q}_i^{+}}{\max_k \overline{Q}_k^{+}},$ $\overline{S}_i^{+} = \frac{\overline{Q}_i^{+}}{\max_k \overline{Q}_k^{+}}$ $\underline{S}_i^{-} = 1 - \frac{\overline{Q}_i^{-}}{\max_k \overline{Q}_k^{+}}$ $\overline{S}_i^{-} = 1 - \frac{\underline{Q}_i^{-}}{\max_k \overline{Q}_k^{+}},$	(21) (22) (23) (24)
Step 6.	Calculate the appraisal score	$S_i = \frac{1}{2}\left[(1-\alpha)\left(\underline{S}_i^{-} + \underline{S}_i^{+}\right) + \alpha\left(\overline{S}_i^{-} + \overline{S}_i^{+}\right)\right]$	(25)
Step 7.	Rank the alternatives	The alternative with the highest S_i is the best choice among the combat unmanned ground platform.	

3. Determination of weighting coefficients of criteria

The army’s demands for optimal combat aircraft for use in various combat operations are very uneven in terms of their tactical and technical characteristics (Žnidaršič et al., 2020), so it is necessary for the decision-maker to define the criteria on the basis of which the alternatives will be compared. In the further part of the paper, the definition of characteristics that have a significant impact on the decision-maker when choosing the most favorable solution for the implementation and equipping of army units was carried out (Li et al., 2023).

Autonomy of movement (C1) integrates several different characteristics of unmanned ground platforms such as remote-control range; the time limit of the use of unmanned ground platforms that depends on the type of energy powered by the unmanned ground platforms. The difference in the concept of autonomy is the difference between automatic and autonomous systems (Wu et al., 2020). The autonomy of movement is expressed in a unit of time (h) or the number of kilometers traveled, in the paper this criterion is expressed in km (Maini et al., 2019; Ramasamy et al., 2022).

Reliability (C2) is one of the most significant exploitation characteristics of unmanned ground platforms, which is expressed in the number of hours of operation without failure and is expressed in percentages. Reliability is the ability of a combat unmanned ground platform to provide required functions under certain conditions of use and over a given period, while keeping the values of the basic characteristics within defined limits.

The maximum payload mass (payload) (C3) is an additional equipment (additional payload) that is placed on the unmanned in the grounding the platform, based on which its type, purpose and class of affiliation are characterized and expressed in kilograms (Lopatka, 2020; Žnidaršič et al., 2020).

Maximum speed (C4) is a characteristic that directly affects the efficiency of the combat system, increasing the maximum speed increases the efficiency and effectiveness of the unmanned ground platform. This characteristic is expressed in the distance traveled in a unit of time (km/h).

Resilience (C5) is a significant characteristic of combat unmanned ground platforms and represents the possibility of surviving combat systems on the battlefield in various conditions characterized by the action of enemies from land, water, and air; electronic, radio, Wi-Fi, and infrared signal jamming, etc. This criterion is of a linguistic type, and translation is carried out using a scale (Raccete et al., 2022; Chuprov, et al., 2023).

Combat capabilities (C6) are the most important characteristic of combat unmanned platforms, which is expressed in the number of destroyed targets with a single combat kit and is directly correlated with the fire capabilities and efficiency of the combat system (Lopatka et al., 2023; Sharma, 2012).

The cost of a single system (combat unmanned ground platform plus accompanying combat equipment) (C7) represents the total cost to be paid for a system with accompanying combat and non-combat equipment. The criterion is of an economic character and a type of "cost". The cost of the system is expressed in thousands of US dollars (USD ($)) (Petrovski et al., 2023).

4. Presentation of research results

Table 5 presents the defined criteria and results of determining the weighting coefficients of criteria by applying expressions 1-10 defined by DIBR method.

Table 5. Value of the Weight Coefficient by DIBR method

Criterion	Value of the Weight Coefficient
C1	0.2582
C2	0.1869
C3	0.1593
C4	0.1251
C5	0.1024
C6	0.0908
C7	0.0773

Table 6 shows the initial decision matrix based on which the ranking of defined alternatives was performed.

Table 6. Initial Decision Matrix

	C_1 max 0.2582		C_2 max 0.1869		C_3 max 0.1593		C_4 max 0.1251		C_5 max 0.1024		C_6 max 0.0908		C_7 min 0.0773	
	l_1	u_1	l_2	u_2	l_3	u_3	l_4	u_4	l_5	u_5	l_6	u_6	l_7	u_7
A_1	3.6	4.0	0.80	0.85	0.93	0.95	28	50	250	275	350	400	80	100
A_2	3.0	3.6	0.78	0.84	0.90	0.93	100	400	270	300	185	240	80	95
A_3	2.9	3.6	0.79	0.84	0.91	0.92	50	300	750	1000	375	425	77	89
A_4	3.4	3.7	0.75	0.83	0.87	0.90	240	320	550	650	260	325	65	85
A_5	3.0	3.4	0.81	0.86	0.88	0.91	500	750	600	750	200	300	100	130
A_6	2.7	3.3	0.82	0.84	0.79	0.84	320	400	70	100	175	250	75	110
A_7	3.5	4.0	0.80	0.83	0.85	0.90	400	500	800	1000	400	450	85	100

The weighted and normalized weighted grey sums of PDA and NDA, obtained by using Equations (17) to (24), are shown in Table 7. The next step is to rank the alternatives. Values of criterion functions for alternatives S_i were calculated using the equation (25). Values S_i and the final ranking of the alternatives are also shown in Table 5.

Table 7. The weighted and the normalized weighted grey sums of PDA and NDA and rank of the alternatives

	$\otimes Q_i^+$		$\otimes S_i^+$		$\otimes Q_i^-$		$\otimes S_i^-$		Si	Ranking
	$\underline{Q}_I^+$	$\overline{Q}_I^+$	$\underline{S}_I^+$	$\overline{S}_I^+$	$\underline{Q}_I^-$	$\overline{Q}_I^-$	$\underline{S}_I^-$	$\overline{S}_I^-$		
A1	0.0066	0.1442	0.0188	0.4106	0.1119	0.2402	0.2002	0.6273	0.314	5
A2	0.0000	0.1389	0.0000	0.3955	0.0442	0.3003	0.0000	0.8528	0.312	6
A3	0.0430	0.2458	0.1225	0.7000	0.0000	0.2126	0.2919	1.0000	0.529	3
A4	0.0000	0.1683	0.0000	0.4793	0.0000	0.1409	0.5308	1.0000	0.503	4
A5	0.0483	0.3093	0.1374	0.8810	0.0000	0.1456	0.5149	1.0000	0.633	2
A6	0.0000	0.1107	0.0000	0.3153	0.0866	0.2997	0.0018	0.7117	0.257	7
A7	0.0642	0.3511	0.1828	1.0000	0.0000	0.0484	0.8389	1.0000	0.755	1

5. Sensitvity analysis

After selecting the most favorable alternative, the sensitivity analysis of the model is conducted as the final step (Pamučar et al., 2012; Pamučar et al., 2016; Bošković et al., 2023). In case of unfavorable results from the sensitivity analysis, the research process is initiated anew to enable its application (Božanić and Pamučar, 2010; Puška et al., 2020; Keshavarz et al., 2023). By employing a specific sensitivity analysis model, favoring a single criterion across all scenarios is achieved, and the analysis is conducted based on changes in the weighting coefficients of the criteria (Tešić et al., 2023; Tešić and Marinković, 2023). In the subsequent part of the paper, nine scenarios are defined, in which changes in the weighting coefficients of the criteria are implemented. The relationships between the rankings of alternatives are assessed in relation to the initial ranking.

The correlation of rankings obtained through changes in weighting coefficients was performed in relation to the initial ranking, in accordance with the defined scenarios, as depicted in Figure 1.

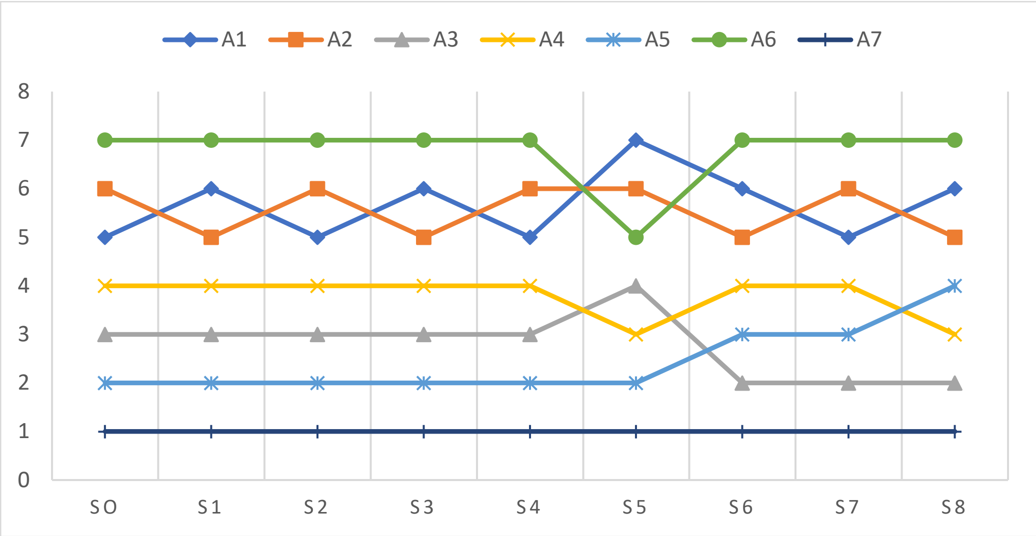

Figure 1. Rank of alternatives by scenarios

Figure 2 displays the Spearman's coefficient values for changes in the weighting coefficients of criteria.

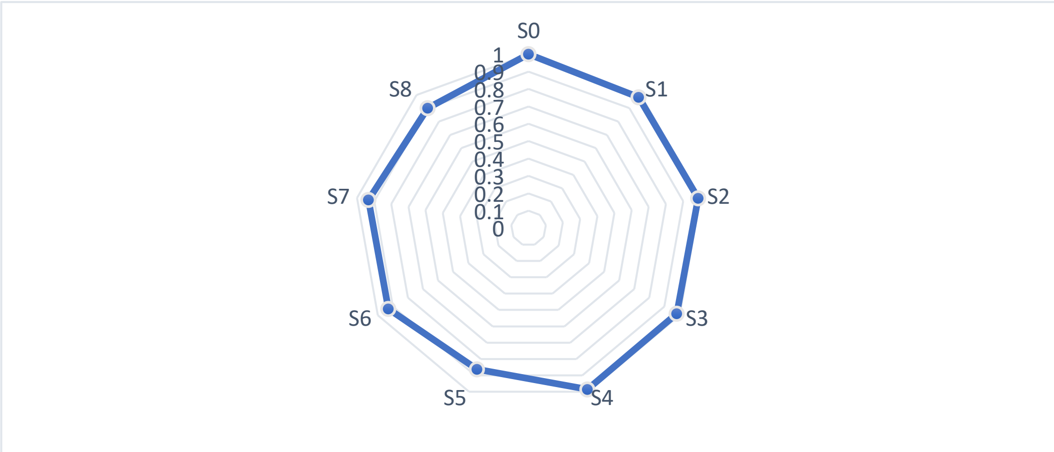

Figure 2. The Spearman's coefficient values in relation to the correlation of rankings for the 9 scenarios

Based on the presented results in Figure 1 and 2, it can be concluded that the rankings of alternatives are highly stable with respect to changes in the weighting coefficients of criteria. The lowest correlation coefficient is [0.75], indicating a very stable correlation coefficient.

6. Conclusion

This paper proposes a new hybrid model that integrates DIBR with grey EDAS method. This is the first time in the literature that this model is applied where positive aspects of DIBR and grey number theory and EDAS multicriteria decision-making methods are integrated. The DIBR-grey EDAS model is presented on the problem of choosing to combat unmanned platforms that are used by different armies of the world to equip units of the army. The DIBR method was used to determine the weighting coefficients of criteria, which were previously defined by experts by analyzing the available literature. By applying grey numbers integrated into the EDAS method, a selection of the best alternative was made from a set of 7 different combat defenseless platforms. The developed model can also be used in other areas to solve various problems of MCDM since it adequately treats uncertainties by applying grey number theory and subjectivity using the DIBR method.

The research results have been confirmed through the application of sensitivity analysis to changes in the weighting coefficients of criteria, where the results obtained using the defined MCDM model have demonstrated a high level of stability.

Further research should be focused on redefining the existing criteria by hiring a larger number of experts and applying different models of MCDM to solve this or similar problems. Also, new research should focus on the development of the DIBR method by applying different theories of uncertainty.

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