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Application of the new hybrid model LMAW-G-EDAS multi-criteria decision-making when choosing an assault rifle for the needs of the army

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Abstract

The paper addresses the selection of the most favorable alternative in the form of assault rifles to meet the requirements arising from modern combat operations. The complexity of the problem, conditioned by the different structural elements of automatic rifles and the specific situations of their use, has caused the application of Multi-Criteria Decision-making (MCDM) methods. A hybrid model was developed to guide the selection of the appropriate automatic rifle. The criteria were defined by experts, where the calculation of the weight coefficients of criteria was performed using the LMAW method Employing the grey EDAS method for MCDM, the study identifies an assault rifle that offers the most advantageous capabilities for carrying out firing tasks in the context of daily combat operations, with the aim of equipping the armed forces and raising the operational capability of the units. The validity of this model was verified through sensitivity analysis involving the adjustment of criteria weight coefficients.

Keywords: Logarithm Methodology of Additive Weights (LMAW), grey theory, Evaluation based on Distance from Average Solution (EDAS), weapons, assault rifle.

1. Introduction

Modern combat operations are carried out within a distinct operational environment influenced by a multitude of factors. These factors have also played a pivotal role in shaping the development of weaponry, with a primary focus on optimizing target impact. A significant place in the modern armies of the world is occupied by automatic rifles as the basic personal armament of most soldiers. A wide array of countries manufacture automatic rifles, leading to a diverse range of options available in the market, each with its unique set of characteristics. Most armies are equipped with multiple models or types of automatic rifles. The structural elements of assault rifles, the quality of materials and workmanship influence the fact that there are significant differences between the models of assault rifles (precision, shooting speed, fire capabilities, number of downtime, etc.).

Due to the diverse requirements of the military for specific characteristics of assault rifles in various operational contexts, the objective was to develop a model capable of selecting the most optimal asssault rifle based on its individual attributes and suitability for the intended use. The results of the research can be used when further procurement of assault rifles for the needs of the military. Hybrid model of multicriteria decision-making LMAW – grey EDAS for the selection of assault rifles can also be used when choosing the most favorable alternative in other areas. One of the objectives of the paper is to determine the weight coefficients of criteria, as one of the complex problems that was realized by the engagement of experts. The contribution of the work is reflected in defining criteria of importance for the selection of the most optimal assault rifle and the formation of a hybrid model that will achieve the goal as well as confirmation of the efficiency of the LMAW – grey EDAS model. The paper is structured into several sections including introduction where an overview of the research topic and its significance are provided; a literature review where the paper reviews relevant literature to provide context for the study. Furthermore, in the materials and method section, LMAW and EDAS methods, along with an explanation of grey numbers elaborated. In the next section, the paper presents the outcomes of the study, including the establishment of criteria and the determination of criterion weights. The fifth section showcases the selection of the most favorable alternative, followed by conducting sensitivity analysis to assess the robustness of the chosen model and lastly, concluding with the significance of the work based on the presented results.

2. Literature review

A variety of quantitative methods have been developed to assist in making certain decisions. These are the most common methods of optimization, which aim to select the optimal solution from the set available, using mathematical modeling of real problems and a set of mathematical tools for solving decision-making problems, and especially multicriteria methods used to solve problems when viewed from several aspects – criteria on which to decide (Paul et al., 2021). Jenkins and Lowrey (2004) conduct a analysis of the shooting weapons used in the U.S. Army and the proposed replacement weapons through quantitative analysis of the characteristics of the weapon "head to head". Bouraima et al. (2024) present a new integrated intelligent decision support system consisting of SWOT analysis, AHP and Combined Trade-off Solution (CoCoSo) within an Intuitionistic Fuzzy (IVIF) Value Framework interval. Dağdeviren et al. (2009) show the selection of optimal weapons using the AHP, TOPSIS and fuzzy TOPSIS methods. Ashari and Parsaei (2014) use electra III to optimize rifles for infantry units. Gordon et al. (2015) conducted a comparative analysis of weapons and military equipment of the U.S. Army and other armies of the world, comparing basic combat characteristics. Radovanović and Stevanović (2020) analyze the technical characteristics of Serbian-made automatic rifles with the aim of equipping units of the Serbian Armed Forces. Božanić et al. (2020) using a hybrid MCDM model composed of two methods: LBWA and MAIRCA modified by interval rough numbers – IR-MAIRCA, select the most favorable submachine gun for the needs of the army. Radovanović et al. (2021) analyze the accuracy and precision of shooting of Serbian-made automatic rifles using the AHP method. Kowalewski (2021) compares and selects the best submachine gun for the needs of service weapons. Dimitrov (2021) propose a new generation of assault rifles and ammunition designed for the needs of the U.S. Military. Woźniak et al. (2021) investigates the development of the MSBS Grot assault rifle from the A0 to the A2 version. Chemezov et al. (2021) presents the results of the ak-109 assault rifle's bullet penetration into targets made of different materials.

Tešić et al. (2022) presents a modification of the DIBR and MABAC method by applying rough numbers in multi-criteria decision-making of the most effective anti-tank missile system. Pamučar et al. (2021) proposes a new framework for multi-criteria decision-making to assess the operational efficiency of logistics service providers using LMAW method. The authors believe that this method provides significant stability and reliability of results in a dynamic environment, especially whilst processing larger data sets. After the introduction of this emerging MCDM framework, studies using this method were found in the literature. Demir (2022b) used the fuzzy LMAW model to develop the scientific calculation of the weights of the dimensions that make up the concept of poverty. Puška et al. (2022) combined the fuzzy LMAW method and fuzzy CRADIS method in order to find a selection of green suppliers within the green agricultural production. Similarly, Puška et al. (2023) utilized the fuzzy rough sets with LMAW method to calculate the criteria weights, with a focus on the quality criterion for green supplier selection in agribusiness. Furthermore, Asadi et al. (2023) employed fuzzy LMAW for the prioritization of positive and negative factors affecting blockchain adoption in SMEs. Lukić (2023) also benefitted from the fuzzy LMAW and MARCOS methods to measure and analyze of the information performance of companies located in the European Union and Serbia.

Ghorabaee et al. (2015) developed the EDAS method based on distance from the average solution. Ghorabaee et al. (2017) using an extended EDAS method with interval type-2 fuzzy sets in multicriteria decision-making. Ulutaş (2017) using the EDAS method makes the selection of sewing machines for the textile industry. Kahraman et al. (2017) employed the IF EDAS method to assess solid waste disposal site options. Ecer (2018) using fuzzy AHP -EDAS model makes a selection of 3PLs providers. Stevic et al. (2019) used the fuzzy AHP-fuzzy EDAS hybrid model to select suppliers. Liang (2020) uses EDAS in a fuzzy environment to evaluate the design of a green building for energy saving. Karatop et al. (2021) used the fuzzy AHP -EDAS-fuzzy FMEA model to analyze decision-making regarding renewable energy investments in Turkey. Menekse and Akdag (2022) selects tools for distance education using the new spherical fuzzy AHP-EDAS model. Rogulj et al. (2022) evalue the application of the EDAS method in fuzzy environments by applying grey numbers to decide on the priority of reconstruction of historic bridges. Terzioglu et al. (2022) perform formwork system selection in building construction projects using an integrated rough AHP-EDAS approach. Akram et al. (2023) study the introduction of the general multi attribute group decision making model by integrating CRiteria Importance Through Intercriteria Correlation (CRITIC) method and EDAS method. Liu and Lin (2010) analyze grey numbers. Datta et al. (2013) analyze the choice of robots using the grey – MULTIMOORA approach. Stanujkic et al. (2017) describe an extended EDAS method based on interval grey numbers. The contribution of the paper is that the application of the model LMAW-grey EDAS multi-criteria decision-making enables the selection of the most optimal alternative (assault rifle) in order to be implemented in the army.

3. Materials and methods

Due to the complexity of the research problem, a hybrid model of LMAW – grey EDAS multicriteria decision-making for the selection of assault rifle for the needs of the army was formed. By engaging experts, the definition of the analysis criteria was carried out, after which the application of the LMAW method determined the weightcoefficients of the criteria. After which, by applying the EDAS method improved with grey numbers, the most favorable alternative (assault rifles) was selected for the needs of the army. The model is based on knowledge of LMAW and EDAS decision-making methods and grey number theory (Figure 1).

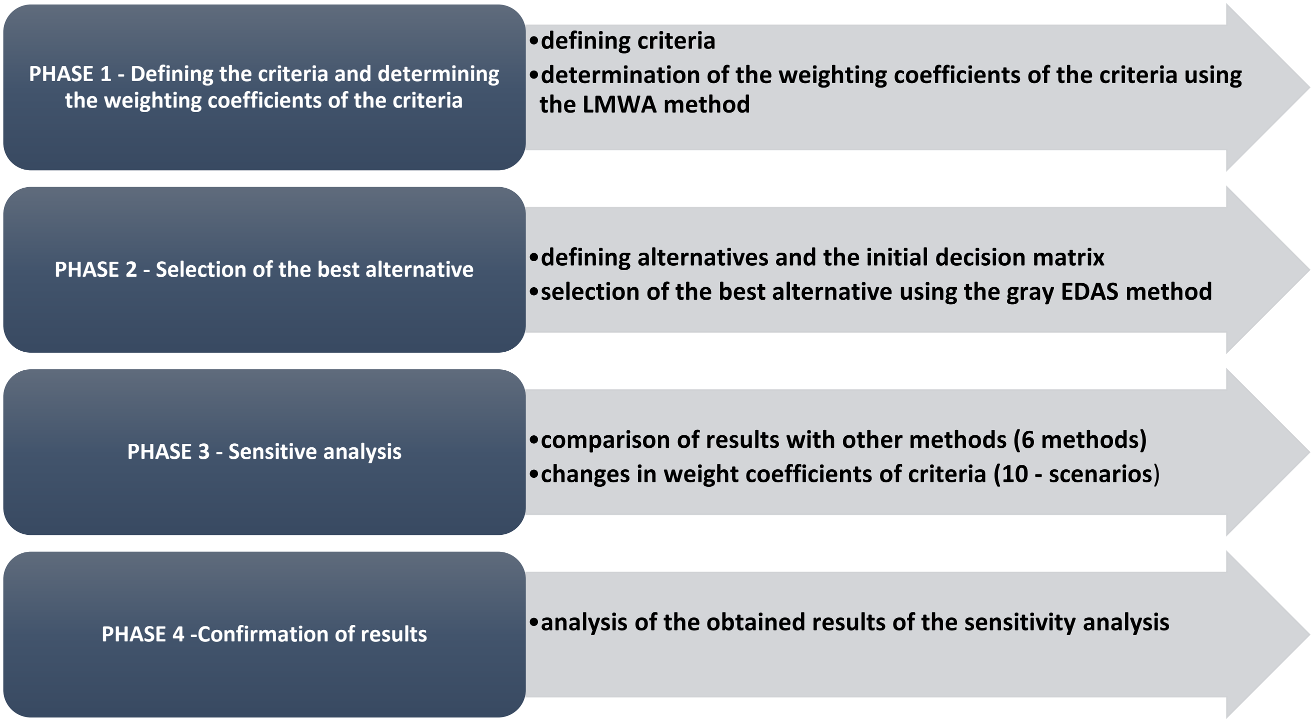

Figure 1. Hybrid model LMAW-grey EDAS

3.1 LMAW method

The LMAW method was first introduced in the paper by Pamučar et al. (2021). The LMAW method is a newer method that can be applied both to determine the weight coefficients of criteria, as well as to select the optimal alternatives from the set offered. 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
Božanić et al. (2022)	Fuzzy LMAW
Yilmaz (2023)	LMAW-CRADIS
Tešić et al. (2023)	Fuzzy LMAW-grey MARCOS
Demir (2022a)	LMAW-DNMA
Puška et al. (2022)	Z-Fuzzy LMAW – Fuzzy CRADIS
Radovanović et al. (2023a)	DIBR-FUCOM-LMAW- grey EDAS
Sıcakyüz (2023)	Fuzzy LMAW-fuzzy WASPAS

Table 2 illustrates the steps involved in the LMAW method.

Table 2. Steps of the LMAW method

Step 1.	*Defining the initial decision matrix (M)*	$\boldsymbol{M^e} = \left[\boldsymbol{\Omega_{ij}}\right]_{\boldsymbol{m \times n}} = \begin{bmatrix} \boldsymbol{\Omega_{11}} & \cdots & \boldsymbol{\Omega_{1n}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{\Omega_{m1}} & \cdots & \boldsymbol{\Omega_{mn}} \end{bmatrix}$	(1)
Step 2.	*Standardization of the decision matrix (ψ)*	$\Omega_{ij} = \begin{cases} \Omega_{ij} = \frac{\Omega_{ij}+\Omega_j^+}{\vartheta_j^+} \quad if \quad K_j = \quad is\ Benefit, \\ \Omega_{ij} = \frac{\Omega_{ij}+\Omega_j^-}{\Omega_{ij}} \quad if \quad K_j = \quad is\ Cost. \end{cases}$	(2)
Step 3.	*Defining a priority vector (Π)*	$\Pi^e = (\psi_{k1}^e, \psi_{k2}^e, \dots, \psi_{km}^e)$	(3)
Step 3a.	*Defining anti-ideal point (ψ_{aip})*	$\psi_{min}^e = \min\{\psi_{k1}^e, \psi_{k2}^e, \dots, \psi_{km}^e\}$	(4)
Step 3b.	*Determining the relationship between the elements of the priority vector and the absolute anti-ideal point (m_{km}^e)*	$m_{km}^e = \frac{\psi_{km}^e}{\psi_{aip}}$	(5)
Step 3c.	*Determining the size of a criteria weight vector (v_j)*	$v_j^e = \frac{\log_\alpha(m_{km}^e)}{\log_\alpha(\beta^e)}, \alpha > 1$ $v_j = \left(\frac{1}{e(e-1)} \sum_{x=!}^{e} (v_j^{(x)})^\pi \sum_{\substack{y=1 \\ y \neq x}}^{e} (v_j^{(y)})^\varrho\right)^{\frac{1}{\pi+\varrho}}$	(6) (7)
Step 4.	*Calculation of weighted matrix elements (Z)*	$\tau_{ij} = \frac{2\lambda_{ij}^{v_j}}{(2-\lambda_{ij})^{v_j}+\lambda_{ij}^{v_j}}$ $\lambda_{ij} = \frac{\ln(\Omega_{ij})}{\ln(\Phi_{i=1}^{n}\Omega_{ij})}$	(8) (9)
Step 5.	*Budget shortening index for ranking definisane alternative (Θ_i).*	$\Theta_i = \sum_{j=1}^{m} \tau_{ij}$	(10)

3.2 The elements of the grey system theory

The grey system theory is identified as an effective methodology that can be used to solve uncertain problems with partially known information. In the grey system theory, all information can be classified into three categories that are labelled with corresponding colours - white, grey and black. There are also several types of grey numbers such as: grey numbers with only upper limits, grey numbers with only lower limits, black and white numbers and so on.

A grey number, denoted as ⊗y, is such a number whose exact value is unknown, but a range within which the value lies is known. A grey number with known upper, *y*, and lower, *y*, bounds but unknown distribution information for *y* is called the interval grey number (Lin et al., 2008):

$$\otimes y = \left[\underline{y}, \overline{y}\right] = \left[y' \in y \,\middle|\, \underline{y} \le y' \le \overline{y}\right] \tag{11}$$

The degree of greyness is an important characteristic of grey numbers, determined as the distance between its bounds $\overline{y} - \underline{y}$.

When the degree of the greyness of an interval grey number increases, i.e., when the distance between such bounds increases and the bounds tends to infinity, $\underline{y} \to -\infty$ and $\overline{y} \to +\infty$, then the interval grey number tends to become a black number. In contrast to the previous one, when the degree of greyness decreases, then the interval grey number tends to become a white number; finaly when upper and lower bounds are equal, $\overline{y} = \underline{y}$, an interval grey number becomes a white (crisp) number.

3.3 The basic operations of interval grey numbers.

Let $\otimes y_1 = \left[\underline{y}_1, \overline{y}_1\right]$ and $\otimes y_2 = \left[\underline{y}_2, \overline{y}_2\right]$ be two interval grey numbers, and *k* is a positive real number. The basic operations of the interval grey numbers $\otimes y_1$ and $\otimes y_2$ are defined as follows (Deng, 1992)

$$\otimes y_1 + \otimes y_2 = \left[\underline{y}_1 + \underline{y}_2, \overline{y}_1 + \overline{y}_2\right] \tag{12}$$

$$\otimes y_1 - \otimes y_2 = \left[\underline{y}_1 - \overline{y}_2, \overline{y}_1 - \underline{y}_2\right] \tag{13}$$

$$\otimes y_1 \times \otimes y_2 = \left[\underline{y}_1 \underline{y}_2,\ \overline{y}_1 \overline{y}_2\right] \tag{14}$$

$$\otimes y_1 \div \otimes y_2 = \left[\frac{\underline{y}_1}{\overline{y}_2}, \frac{\overline{y}_1}{\underline{y}_2}\right] \tag{15}$$

$$k \otimes y_1 = k \otimes \left[\underline{y}_1, \overline{y}_1\right] = \left[k\underline{y}_1, k\overline{y}_1\right]. \tag{16}$$

The whitened value. The whitened value of an interval grey number $y_{(\alpha)}$ is a crisp number whose possible values lie between the upper and lower bounds of the interval grey number $\otimes$*y.* For the given interval grey number $\otimes y = \left[\underline{y}, \overline{y}\right]$ the whitened value $y_{(\alpha)}$ can be determined as follows:

$$y_{(\lambda)} = (1 - \lambda)\ \underline{y} + \lambda \overline{y} \tag{17}$$

where λ denotes the whitening coefficient and $\lambda \in [0,1]$. In the particular case, when $\lambda = 0.5$ Equation (18) obtains the following form:

$$y_{(\lambda=0.5)} = \frac{1}{2}\left(\underline{y} + \overline{y}\right). \tag{18}$$

3.4 Grey EDAS method

The EDAS approach was first submitted to the literature by Ghorabaee et al. (2015) as a new multi-criteria decision-making method. Unlike previous distance-based approaches, it determines the criteria's mean values rather than using the distance between the ideal and non-ideal values as the basis. This mean value and positive and negative distance measurements are used to evaluate alternatives. 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
Stanujkic et al. (2017)	Grey EDAS
Karasan and Kahraman (2018)	EDAS
Peng et al. (2017)	Fuzzy MABAC-EDAS
Peng and Liu (2017)	EDAS
Ghorabaee et al. (2017)	Fuzzy EDAS
Stevic et al. (2019)	Fuzzy AHP-EDAS

The basic ideas of the EDAS method are the use of two distance measures, namely the Positive Distance from Average (PDA) and the Negative Distance from Average (NDA); and that the evaluation of the alternatives is done according to higher values of the PDA and lower values of the NDA.

When considering the problem of making a decision in which *m* alternatives are evaluated with *n* criteria, and where the characteristics of the alternatives are not exactly known, they are presented as a gray number $\otimes y_{ij} = \left[\underline{y}_{ij}, \overline{y}_{ij}\right]$ where $\underline{y}_{ij}$ i $\overline{y}_{ij}$ denote the minimal and the maximal expected performance ratings of the alternative i with respect to the criterion j.

Then, the computational procedure of the proposed extension of the EDAS method can be expressed concisely through the following steps (Stanujkic et al., 2017) in table 4:

Table 4. Steps of the grey EDAS method

Step 1.	Construct the grey decision-making matrix (Y)	$\otimes Y = \begin{bmatrix} [\underline{y}_{11}, \overline{y}_{11}] & [\underline{y}_{12}, \overline{y}_{12}] & \cdots & [\underline{y}_{1n}, \overline{y}_{1n}] \\ [\underline{y}_{21}, \overline{y}_{21}] & [\underline{y}_{22}, \overline{y}_{22}] & \cdots & [\underline{y}_{2n}, \overline{y}_{2n}] \\ \cdots & \cdots & \cdots & \cdots \\ [\underline{y}_{m1}, \overline{y}_{m1}] & [\underline{y}_{m2}, \overline{y}_{m2}] & \cdots & [\underline{y}_{mn}, \overline{y}_{mn}] \end{bmatrix}$	(19)
Step 2.	Determine the grey average solution according to all criteria	$\otimes Y_j^{\circ} = \left([\underline{y}_1^{\circ}, \overline{y}_1^{\circ}], [\underline{y}_2^{\circ}, \overline{y}_2^{\circ}], \ldots, [\underline{y}_n^{\circ}, \overline{y}_n^{\circ}]\right)$	(20)
Step 3.	Calculate the grey positive distance from average, $\otimes \mathrm{d}_{ij}^{+} = [\underline{\mathrm{d}}_{ij}^{+}, \overline{\mathrm{d}}_{ij}^{+}]$, and the grey negative distance from average $\otimes \mathrm{d}_{ij}^{-} = [\underline{\mathrm{d}}_{ij}^{-}, \overline{\mathrm{d}}_{ij}^{-}]$,	$\underline{d}_{ij}^{+} = \begin{cases} \frac{max\left(0,\left(\underline{y}_{ij} - \overline{y}_j^{\circ}\right)\right)}{0.5\left(\underline{y}_j^{\circ} + \overline{y}_j^{\circ}\right)}; & j \in \Omega_{max} \\ \frac{max\left(0,\left(\underline{y}_j^{\circ} - \overline{y}_{ij}\right)\right)}{0.5\left(\underline{y}_j^{\circ} + \overline{y}_j^{\circ}\right)}; & j \in \Omega_{min} \end{cases}$	(21)
		$\overline{d}_{ij}^{+} = \begin{cases} \frac{max\left(0,\left(\overline{y}_{ij} - \overline{y}_j^{\circ}\right)\right)}{0.5\left(\underline{y}_j^{\circ} + \overline{y}_j^{\circ}\right)}; & j \in \Omega_{max} \\ \frac{max\left(0,\left(\underline{y}_j^{\circ} - \underline{y}_{ij}\right)\right)}{0.5\left(\underline{y}_j^{\circ} + \overline{y}_j^{\circ}\right)}; & j \in \Omega_{min} \end{cases}$	(22)
		$\underline{d}_{ij}^{-} = \begin{cases} \frac{max\left(0,\left(\underline{y}_j^{\circ} - \overline{y}_{ij}\right)\right)}{0.5\left(\underline{y}_j^{\circ} + \overline{y}_j^{\circ}\right)}; & j \in \Omega_{max} \\ \frac{max\left(0,\left(\underline{y}_{ij} - \underline{y}_j^{\circ}\right)\right)}{0.5\left(\underline{y}_j^{\circ} + \overline{y}_j^{\circ}\right)}; & j \in \Omega_{min} \end{cases}$	(23)
		$\overline{d}_{ij}^{-} = \begin{cases} \frac{max\left(0,\left(\underline{y}_j^{\circ} - \underline{y}_{ij}\right)\right)}{0.5\left(\underline{y}_j^{\circ} + \overline{y}_j^{\circ}\right)}; & j \in \Omega_{max} \\ \frac{max\left(0,\left(\overline{y}_{ij} - \underline{y}_j^{\circ}\right)\right)}{0.5\left(\underline{y}_j^{\circ} + \overline{y}_j^{\circ}\right)}; & j \in \Omega_{min} \end{cases}$	(24)
Step 4.	Determine the weighted sum of the grey positive distance from average (PDA), $\otimes \mathrm{Q}_{\mathrm{i}}^{+} = [\underline{\mathrm{Q}}_{\mathrm{i}}^{+}, \overline{\mathrm{Q}}_{\mathrm{i}}^{+}]$ and the weighted sum of the grey negative distance from average (NDA), $\otimes \mathrm{Q}_{\mathrm{i}}^{-} = [\underline{\mathrm{Q}}_{\mathrm{i}}^{-}, \overline{\mathrm{Q}}_{\mathrm{i}}^{-}]$	$\underline{Q}_i^{+} = \sum_{j=1}^{n} w_j \underline{d}_{ij}^{+},$	(25)
		$\overline{Q}_i^{+} = \sum_{j=1}^{n} w_j \overline{d}_{ij}^{+},$	(26)
		$\underline{Q}_i^{-} = \sum_{j=1}^{n} w_j \underline{d}_{ij}^{-},$	(27)
		$\overline{Q}_i^{-} = \sum_{j=1}^{n} w_j \overline{d}_{ij}^{-}.$	(28)
Step 5.	Normalize the values of the weighted sum of the grey PDA and the weighted sum of the grey NDA for all alternatives	$\underline{S}_i^{+} = \frac{\underline{Q}_i^{+}}{\max_k \overline{Q}_k^{+}},$	(29)
		$\overline{S}_i^{+} = \frac{\overline{Q}_i^{+}}{\max_k \overline{Q}_k^{+}}$	(30)
		$\underline{S}_i^{-} = 1 - \frac{\overline{Q}_i^{-}}{\max_k \overline{Q}_k^{+}}$	(31)
		$\overline{S}_i^{-} = 1 - \frac{\underline{Q}_i^{-}}{\max_k \overline{Q}_k^{+}},$	(32)
Step 6.	Calculate the appraisal score $\mathrm{S_i}$	$S_i = \frac{1}{2}\left[(1-\alpha)\left(\underline{S}_i^{-} + \underline{S}_i^{+}\right) + \alpha\left(\overline{S}_i^{-} + \overline{S}_i^{+}\right)\right]$	(33)
Step 7.	Rank the alternatives according to the decreasing values of appraisal score	The alternative with the highest S_i is best alternative (assault rifle).	

4. Illustrative example and results (Defining criteria and determining the weighting coefficients of criteria)

The specificity and complexity of the research problem caused that in the first phase of the application of the model, by hiring experts, criteria that affect the selection of the most optimal alternative (assault rifle) should be carried out. For the selection of the best alternative (assault rifle), ten criteria are defined that have an impact on the choice (Goździk et al, 2019) .

The probability of hitting (C_1) is a numerous measure of objective possibility to hit the target in certain shooting conditions (Kokelj and Ranđelović, 2018). The results of the probability of hitting make it possible to determine the required consumption of ammunition and mathematical expectation of the number of immediate hits, where, based on the time required for shooting, the degree of effectiveness of immediate shooting is defined. It is expressed in percentages.

The size of the probability of guessing depends on:

1. mean point of impact (Mp) relative to the target center. When the middle hit is closer to the center of the target, then the probability of hitting is also higher, because the target will cover that part of the surface of the dispersal where the hits are denser;
2. the size of the target, when the middle hit coincides with the middle of the goal in conditions of the same images of the hit, the probability of hitting is higher when the dimensions of the goal are larger;
3. the size of disperion area, the probability of hitting targets of the same dimensions is higher when the bullets disperion area (the ellipse of the dispersal) is smaller and
4. target direction, when the target has a small depth and a large width and vice versa, the highest probability of hitting will be when the direction of the shooting coincides with the longer azis of the target.

Shooting precision (C_2) represents the measuring size of the shot dispersal image limited by four probable turns (Vs) to each side from the middle hit. Smaller scattering creates a smaller image of the trajectory beam hit, which makes the tool more precise. The precision of shooting is prescribed according to the size of the shot image, and is expressed in the MOA (Minute Of Angle).

Reliability (C_3) is a very important ezploitation characteristic of a weapon that is ezpressed in the number of stops compared to the number of shots fired. It is very important that weapons can be used in different combat conditions, at high and low temperatures, with dirty parts, at different positions of assault rifles and others. Assault rifles are a safe weapon, but after prolonged use it is possible to appear malfunctions that cause delays during firing. The most common causes that lead to shooting jams are: wear and tear of parts, malfunction of ammunition, poor maintenance and careless and unprofessional handling (Ranđelović and Komazec, 2016).

Effective range (C_4) is the distance (in meters) at which it is ezpected to hit the target with a sufficient amount of kinetic energy of the grain to neutralize the target. Greater effective range provides action at greater distances, which enables greater safety and protection for C_4 the shooter (Radovanović et al., 2023b). Greater effective range increases the effectiveness of the assault rifle.

The service life of the tube (C_5) is a characteristic defined by the number of shots fired, without the characteristics of the pipe slipping significantly and are within the set limits. The method of manufacture and the types of materials used in the manufacture of pipes have a crucial impact on its service life as well as the pressure and temperature that are created in the pipe after firing (Fikus et al., 2022). The most common standard tolerated for caliber deviations is 0.07 mm, and the corrosion of pipes over 50% directly affects the accuracy and precision of shooting.

Theoretical rate of fire (C_6) is an important feature for maximizing the effect on the target. C_6 In the combat qualities of assault rifles, theoretical and practical rate of fire are distinguished *Theoretical rate of fire* is a combat characteristic that is ezpressed in the mazimum number of shots fired per minute (rounds/min) with continuous automatic operation (Fikus and Trębiński, 2020). It can be calculated making use of single shot operation cycle time assault rifle is also the number of bullets fired in one minute and it exerts a significant impact on the performance of combat actions and the ezecution of set fire tasks. This characteristic is important for any weapon, because the higher shooting speed is directly related to the density of the fire, and the greater density of fire is achieved by mazimizing the effect on the target. Increasing the density of fire also increases the likelihood of hitting the target. The higher speed of shooting directly affects the efficiency of the assault rifle. The practical speed of shooting is determined by experimental route or calculation by the pattern given by B.A. Malinovski (Tančić et al., 2009):

$$n = \frac{60}{\frac{t_n}{s} + t_c + \frac{t_p}{e}} \tag{34}$$

where t_n it represents the time, t_p time of loading the weapon, t_c the duration of one cycle of automatic operation, the number of bullets in the warehouse (frame, band) and the number of bullets in the burs .

The price (C_7) is the price to pay for an assault rifle. The criterion is of an economic character and a type of "cost". This criterion is important for the selection of the most favorable solution due to the different characteristics, and thus the price of assault rifles and the need for a significant number of assault rifles to equip units of the army.

The muzzle velocity (C_8) is the speed achieved by the grain at the moment of leaving the mouth of the assault rifle barrel and represents the distance traveled in a unit of time (m/s). The higher initial rate of the bullet directly affects the firing capabilities of the assault rifle, which increases both the kinetic energy of the bullet, and therefore the effect (degree of materialization) on the target (Jenkins and Lowrey, 2004). With greater initial speed, the accuracy of the assault rifle increases, which directly leads to an increase in the efficiency of the assault rifle.

The mass of weapons (C_9) is an important structural feature of an assault rifle, because the modern way of carrying out operations (e.g. combat in urban space) requires the use of small-mass assault rifles. The mass of weapons directly affects the mobility and the possibility of fire transfer (Radovanović et al., 2023b). In order to make low-mass assault rifles, manufacturers use new types of materials, and most often polymers. Assault rifles whose parts are made of such materials are less mass and their characteristics are the same, as in assault rifles whose parts are made of metal. The mass of the weapon is expressed in kilograms. Lower mass increases user mobility, simpler and faster handling, which increases efficiency in performing combat tasks.

The length of the assault rifle (C_{10}) It is the distance (in millimeters) between the top of the mouth of the tube and the shoulder support on the butt. It is an important characteristic that most affects the handling and carrying of assault rifles, as a shooting weapon. The longer length of the assault rifle reduces the mobility of the shooter, and in a small area, handling is more demanding. For this reason, and with the aim of more efficient use of assault rifles by the user-shooter in solving combat tasks, it tends to a smaller length of the assault rifle, with a telescopic butt. In this way, mobility increases and provides easier handling in reduced space (Radovanović and Stevanović, 2020). Modern assault rifles are most commonly with a folding stock, or with a telescopic-type butt, which significantly reduces their length, allowing easier and faster handling. This can significantly increase efficiency, but it can also reduce accuracy during shooting.

5. Choosing the most favorable alternative (assault rifles)

Table 5 shows a linguistic scale for ranking criteria, using LBWM method expressions, ranking criteria and determining their weighting coefficients of criteria, and the results are shown in Table 6.

Table 5. Lingvistic scale

Linguistic Variables	Abbreviation	Prioritization
Absolutely High	AH	5
Very High	VH	4.5
High	H	4
Medium High	MH	3.5
Equal	E	3
Medium	M	2.5
Low	L	2
Very Low	VL	2.5
Absolutely Low	AL	1

Table 6. Weight coefficients of criteria

Criterion	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Aggregated Weight Coefficient Vectors	0.1274	0.1310	0.1308	0.1185	0.1022	0.1049	0.0905	0.0848	0.0687	0.0408

The first step in implementing the grey EDAS method requires defining the initial decision matrix (Table 7), while Table 8 shows the grey mean values of the criteria.

Table 7. Initial Decision Matrix

	C_1		**C_2**		**C_3**		**C_4**		…	**C_8**		**C_9**		**C_{10}**	
	max		min		max		max		…	max		min		min	
	0.1274		0.1310		0.1308		0.1185		…	0.0848		0.0687		0.0408	
	l_1	u_1	l_2	u_2	l_3	u_3	l_4	u_4	…	l_8	u_8	l_9	u_9	l_{10}	u_{10}
A_1	90	90	3	4	0.98	0.98	400	600	…	900	920	3	3.361	502	617
A_2	95	95	1.3	2	0.98	0.98	500	700	…	745	825	4	4.608	855	1082
A_3	90	90	3	4	0.99	0.99	300	500	…	800	900	3.27	3.81	855	901
A_4	94	94	3.2	3.8	0.98	0.98	400	500	…	796	894	3.31	3.54	812	910
A_5	93	93	4	4.5	0.98	0.98	400	500	…	850	850	3.29	3.58	780	889
A_6	92	92	3.2	4	0.99	0.99	600	650	…	714	850	3.29	3.58	800	965
A_7	94	94	1.5	2	0.96	0.96	600	680	…	900	920	3	3.31	813	914
A_8	93	93	2	3	0.97	0.97	400	500	…	856	914	3.4	3.6	875	930
A_9	94	94	2.5	3	0.95	0.95	450	550	…	800	900	3.5	3.7	780	850
A_{10}	95	95	1.2	1.8	0.9	0.9	600	800	…	840	880	2.9	3.34	610	740
A_{11}	96	96	1.2	2	0.98	0.98	600	650	…	880	930	3.6	4.4	828	902
A_{12}	94	94	2	2.5	0.98	0.98	700	800	…	900	940	3.5	3.7	688	922
A_{13}	92	92	3	4	0.98	0.98	440	500	…	880	900	3.7	3.9	602	820
A_{14}	94	94	3	4	0.98	0.98	500	600	…	840	860	3.7	3.9	605	850
A_{15}	91	91	4	4.5	0.97	0.97	350	500	…	715	750	3.47	3.6	645	943
A_{16}	95	95	2	2.4	0.98	0.98	300	500	…	840	910	3.2	3.6	586	824
A_{17}	93	93	2.3	2.5	0.97	0.97	600	800	…	810	840	3.3	3.5	605	800
A_{18}	94	94	2	3	0.96	0.96	500	1200	…	900	940	3.39	4.98	580	825

Table 8. The grey average solution

	C_1		C_2		C_3		C_4		…	C_8		C_9		C_{10}	
	l_1	u_1	l_2	u_2	l_3	u_3	l_4	u_4	…	l_8	u_8	l_9	u_9	l_{10}	u_{10}
$\otimes x_j^{\circ}$	90	90	3	4	0.98	0.98	400	600	…	900	920	3	3.361	502	617

Based on the data presented in Table 8 and using Equations (21) and (22) the calculations were grey positive distance from the mean and using Equations (23) and (24) the grey negative distance was calculated. The weighted and normalized weighted grey sums of PDA and NDA, obtained by using Equations (25) to (32), are shown in Table 8. Determining the ranks of alternatives is the next step. The values of the criterion functions for alternatives S_i are calculated using the Equations (33). The values and final rank of alternatives are also shown in Table 9.

Table 9. The weighted and the normalized weighted grey sums of PDA and NDA and rank of the alternatives using the grey EDAS method.

	$\otimes Q_i^+$		$\otimes S_i^+$		$\otimes Q_i^-$		$\otimes S_i^-$		Si	*Ranking*
	$\underline{Q}_I^+$	$\overline{Q}_I^+$	$\underline{S}_I^+$	$\overline{S}_I^+$	$\underline{Q}_I^-$	$\overline{Q}_I^-$	$\underline{S}_I^-$	$\overline{S}_I^-$		
A_1	0.0344	0.1980	0.1051	0.6054	0.0029	0.1139	0.5335	0.9881	0.558	4
A_2	0.0160	0.1137	0.0491	0.3477	0.0067	0.2443	0.0000	0.9724	0.342	16
A_3	0.0016	0.0859	0.0049	0.2627	0.0039	0.2138	0.1247	0.9841	0.344	15
A_4	0.0116	0.1201	0.0355	0.3672	0.0097	0.1820	0.2550	0.9603	0.404	12
A_5	0.0008	0.0686	0.0023	0.2096	0.0301	0.2165	0.1135	0.8768	0.301	18
A_6	0.0118	0.1072	0.0361	0.3278	0.0026	0.1834	0.2490	0.9895	0.401	14
A_7	0.0191	0.1539	0.0584	0.4704	0.0165	0.1183	0.5155	0.9323	0.494	6
A_8	0.0055	0.0998	0.0168	0.3051	0.0015	0.1596	0.3465	0.9939	0.416	11
A_9	0.0006	0.0968	0.0020	0.2959	0.0044	0.1634	0.3309	0.9821	0.403	13
A_{10}	0.0221	0.2366	0.0675	0.7235	0.0070	0.0762	0.6882	0.9712	0.613	1
A_{11}	0.0169	0.1374	0.0518	0.4200	0.0016	0.1377	0.4361	0.9935	0.475	7
A_{12}	0.0191	0.2205	0.0584	0.6740	0.0000	0.0876	0.6414	1.0000	0.593	3
A_{13}	0.0008	0.1524	0.0023	0.4660	0.0011	0.1526	0.3750	0.9953	0.460	10
A_{14}	0.0014	0.1546	0.0043	0.4726	0.0000	0.1496	0.3875	1.0000	0.466	9
A_{15}	0.0172	0.1284	0.0526	0.3926	0.0346	0.2355	0.0358	0.8585	0.335	17
A_{16}	0.0097	0.1974	0.0298	0.6034	0.0226	0.1631	0.3323	0.9076	0.468	8
A_{17}	0.0000	0.1944	0.0000	0.5945	0.0054	0.0960	0.6072	0.9778	0.545	5
A_{18}	0.0088	0.3271	0.0270	1.0000	0.0009	0.1451	0.4059	0.9961	0.607	2

6. Sensitivity analysis

Analysis of the sensitivity of the model, is the last step that is necessary to apply (Pamučar et al., 2012). Weak results of sensitivity analysis take the entire research process back to the beginning (Pamučar et al., 2016; Tešić et al., 2022), to look at the possibility of application in practice. There are different approaches to model sensitivity analysis, and most often the authors in their papers apply sensitivity analysis by changing the weight coefficients of criteria (Božanić et al., 2020). This analysis involves evaluating alternatives based on different weighting coefficients of criteria, i.e., by favouring one criterion in each scenario. In this study, 12 scenarios were defined, through the change in the weight coefficients of criteria (Table 10).

The correlation of ranks obtained by changing the weighting coefficients was carried out in relation to the initial ranking, in accordance with the defined scenarios shown in Table 10. Figure 2 shows the values of the Spirman's coefficients for changes in the weight coefficients of criteria.

Table 10. Values of the weight coefficients of criteria in relation to the scenario

	S0	*S1*	*S2*	*S3*	*S4*	*S5*	*S6*	*S7*	*S8*	*S9*	*S10*	*S11*
C_1	0.1274	0.1	0.25	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
C_2	0.1310	0.1	0.083	0.25	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
C_3	0.1308	0.1	0.083	0.083	0.25	0.083	0.083	0.083	0.083	0.083	0.083	0.083
C_4	0.1185	0.1	0.083	0.083	0.083	0.25	0.083	0.083	0.083	0.083	0.083	0.083
C_5	0.1022	0.1	0.083	0.083	0.083	0.083	0.25	0.083	0.083	0.083	0.083	0.083
C_6	0.1049	0.1	0.083	0.083	0.083	0.083	0.083	0.25	0.083	0.083	0.083	0.083
C_7	0.0905	0.1	0.083	0.083	0.083	0.083	0.083	0.083	0.25	0.083	0.083	0.083
C_8	0.0848	0.1	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.25	0.083	0.083
C_9	0.0687	0.1	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.25	0.083
C_{10}	0.0408	0.1	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.25

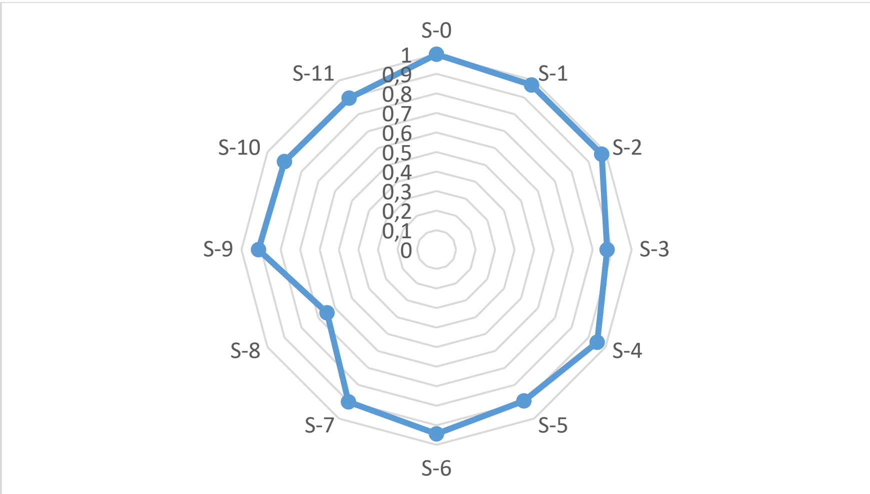

Figure 2. The values of the Spearman's coefficient of the rank correlations for 12 scenarios with the changes in weight coefficients of the criteria in relation to the initial rank of alternatives.

Correlation coefficients of 12 scenarios by changing the values of the weight coefficients of the criteria shown in Figure 2 tend to ideal positive correlation. The lowest correlation in relation to other criteria has the Criterion *C7* – price because the cost of an assault rifle is inversely proportional to the tactical-technical and combat characteristics of the assault rifle. Based on the results shown in Figure 2, it is concluded that the LMAW – grey EDAS model can be used in other areas where there are several different alternatives and criteria.

6. Conclusions

The selection of the assault rifle in the paper was done using the LMAW - grey EDAS model, which, according to the given criteria, is the most favorable for equipping military units. All stages of development and application of the MCDM model have been presented. Criteria of importance for the selection of assault rifles and calculation of their weight coefficients using the LMAW method are defined. This method has proven to be very useful and simple in the process of collecting data from experts. The selection of the most assault rifle was made by the EDAS method, which was improved by the application of grey numbers. The application of grey numbers significantly improved the decision-making process, because it opened the possibility for viewing the entire possibilities of all assault rifles.

In the paper, an analysis of the sensitivity of the model was carried out. The results obtained by sensitivity analysis show that the ranks of alternatives change depending on the weight coefficients. Changes in rankings when changing the weight coefficients of criteria, showed the dominance of the first-ranked alternatives. This is very important because it indicates that the model gives the same or similar results regardless of possible minor errors, which can occur in the process of defining the weighting coefficients of criteria, as a consequence of the subjectivity of experts or decision makers. The MCDM model can also be applied in other areas.

Further research should be focused on expanding and defining additional criteria of importance for the selection of assault rifles for the needs of the armed forces and the improvement of the LMAW and EDAS methods MCDM.

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