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Application of the CRITIC–MARCOS model for ranking infantry weapons based on experimental determination of projectile muzzle velocities

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Abstract
Background/Aim: The aim of this study is to rank small arms using the CRITIC–MARCOS multi-criteria decision-making model, based on experimentally measured projectile muzzle velocities and an assessment of barrel condition. The reference muzzle velocity values were obtained from the relevant regulations and technical manuals. Given that the study encompasses infantry weapons of different calibers, purposes, and design characteristics, experts in mechanical engineering and military sciences defined six evaluation criteria to enable a more realistic comparison of weapon systems with different projectile muzzle velocity characteristics. **Methods:** The experimental measurement of projectile muzzle velocities was conducted using the Garmin Xero C1 Pro radar chronograph. The objective CRITIC method was applied to determine the weights of the evaluation criteria, while the MARCOS method was subsequently used to rank the weapons based on the defined criteria. **Results:** The results revealed deviations between reference and measured muzzle velocities, depending on weapon type, caliber, and ammunition. Chrome-lined barrels demonstrated better performance. The CRITIC–MARCOS model ranked the M19 rifle (7.62 mm) first and the M76 sniper rifle (7.9 mm) last. The M93 rifle (12.7 mm) ranked third with the smallest deviation, the CZ99 pistol (9 mm) second, the M84 machine gun (7.62 mm) fourth, and the M21 assault rifle (5.56 mm) fifth with the largest deviation. **Conclusion:** The ranking of infantry weapons based on experimentally measured projectile muzzle velocities and barrel condition, obtained using the proposed CRITIC–MARCOS model, indicates its potential for the objective assessment and comparison of the performance of different weapon systems. The obtained results can serve as a basis for improving weapon testing and technical condition assessment procedures, as well as for planning future research aimed at a more detailed analysis of individual weapon categories, taking into account their specific design characteristics and operational conditions.

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1. Introduction

The reliability and technical condition of infantry small arms are important factors affecting their functionality and safety during service. The technical characteristics of weapons and ammunition are specified in relevant military regulations and technical documentation. However, actual performance may deviate from reference values due to various technical and operational factors, making experimental verification essential for assessing weapon condition and reliability.

Projectile muzzle velocity is an important parameter for evaluating the technical performance of small arms. It depends on ammunition characteristics, weapon design, and barrel condition. During service, barrel wear and erosion may affect measured muzzle velocities, while variations between individual shots provide information about the consistency of the results. Modern measuring devices enable experimental determination of muzzle velocities and comparison with reference values specified in applicable military regulations.

Comparing weapons of different calibers, purposes, designs, and operating principles is a complex task that cannot be adequately addressed using a single performance indicator. Multi-criteria decision-making (MCDM) methods provide a systematic framework for evaluating alternatives based on several technical and operational criteria. However, the available scientific literature appears to offer limited evidence of studies specifically addressing the ranking of different types of small arms based on experimentally measured projectile muzzle velocities combined with other relevant characteristics.

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In this study, a GARMIN radar device is used to measure projectile muzzle velocities and compare the experimental results with the corresponding reference values. The evaluation also considers selected technical and operational characteristics, including barrel condition and service history. Standard deviation is used to characterize the variability of the measured velocities and assess shot-to-shot consistency.

The CRITIC method is employed to determine the objective weights of the evaluation criteria, taking into account their contrast intensity and intercriteria correlations, while the MARCOS method is used to rank the alternatives relative to ideal and anti-ideal solutions. The combination of these methods provides a systematic framework for integrating experimental measurements and technical-operational characteristics into a comparative evaluation of weapons. The reliability of the resulting ranking can additionally be examined through sensitivity analysis.

By analyzing the literature, it can be concluded that multi-criteria decision-making and methods CRITIC and MARCOS. Both methods have been extensively employed in numerous studies in both the social and natural sciences, supporting decision-making in a wide range of civilian and military applications: Altuntaş [1] use an integrated CRITIC-MARCOS and Entropy-MARCOS framework for electric bus selection; Akpınar [2] for brokerage firm selection in capital markets; Jafari & Naghdi Khanachah [3]for evaluating knowledge management solutions through critical success factors; Shirzadi et al. [4] environmental risk assessment and prioritization of a combined cycle power plant; Chen et al. [5] for optimising sustainable innovation in complex product development systems; Biswas & Basak [6] for developing an efficient supplier performance evaluation and selection process; Canbulut [7] use CRITIC-MARCOS methods for efficient waste management solutions; Shahin et al. [8] use an interval-valued circular intuitionistic fuzzy MARCOS method for renewable energy source selection; Sianturi et al. [9] for data-driven prioritization; Qayyimah & Lazulfa [10] for selecting the best teacher at Madrasah Ibtidaiyah; Kaya & Yöndem [11] for student admission in applied engineering projects; Ekayulianti & Cholil [12] for selecting tourist destination in Semarang; Ullah et al. [13] use CRITIC–WASPAS Method for Business-oriented Stock Market Decision Analysis; Dudic et al. [14] evaluating innovation levels based on standard deviation of parameters; Vellaisamy et al. [15] for optimization of Al 6063 turning process parameters; Atabati & Arabi [16] for optimal solar power plant site selection in fars province-Iran; Sarkar et al. [17] use CRITIC Method in Multi-Criteria Decision Making: A Comprehensive Review of Subjective, Objective, and Hybrid Approaches; Palanisamy et al. [18] for process parametric optimization of a milling process; Nedeljkovic et al. [19] use CRITIC CoCOsO Model for Selection of Robots in Precision Agriculture; Radovanović et al. [20] for evaluation of university professors; Khalilzadeh et al. [21] Using the DEMATEL–MARCOS Method for Identification and Ranking of Human Resource-Related Risks Considering Secondary and Residual Risks in Water Transfer Projects; Govedarica et el. [22] for the selection of plum varieties; Blagojevic et al. [23] for selecting logistics service providers; Younis et al. [24] for optimizing renewable energy investments; Roshanravan et al. [25] for mineral potential modelling; Karbakhsh-ravari & Sarmadian [26] for land suitability assessment; Dehghani et al. [27] for municipal solid waste landfill site selection; Ali et al. [28] for urban bridge assessment; Dewi et al. [29] for evaluating sealing machines in small and medium enterprises; Puška et al. [30] for ethical dimensions in supplier selection sustainability were investigated; Guria et al. [31] for landslide susceptibility assessment in wayanad District; Andrejic & Pajic [32] for strategic decision-making in cold chain logistics; Krishnan [33] use CRITIC method for a visual analysis of bibliographic data; Yang & Tat [34] use CRITIC in study on tourism development; Mao et al. [35] in their work "New approach for quality function deployment based on linguistic distribution assessments and CRITIC method"; Yalçın et al. [36] use the CRITIC-MABAC Method for Evaluating Financial Performance of Companies in the Borsa Istanbul; Arshad et al. [37] use CRITIC Weighting Method and Multi-Atributive Ideal-Real Comparative Analysis in Staff Admissions; Van [38] presents a study on the hybridization of Multi-Criteria Decision-Making; Mishra et al. [39] for solving the sustainable circular supplier selection problem; Demir et al. [40] for a comprehensive bibliometric analysis; El-Araby et al. [41] for location selection problem in the presence of conflicting criteria; Zhao et al. [42], for digital economy development comprehensive evaluation of 31 provincial level regions in China; El-Araby [43] for different engineering applications: a comparative study; Tešić et al. [44] for selection of a dump truck.

Building on the identified research gap in the existing literature, this study aims to contribute to the advancement of approaches for the objective assessment and ranking of infantry small arms based on experimentally determined projectile muzzle velocities and selected technical and operational characteristics. The scientific contribution of the study lies in integrating experimental results with a systematic assessment of different types of weapons, taking into account deviations of measured muzzle velocities from reference values, measurement variability, and barrel condition. In this way, the study expands existing knowledge of the possibilities for comparative assessment of weapons with different design and functional characteristics and provides a basis for further research in the field of technical evaluation and selection of infantry small arms.

2. Materials and Methods

2.1. Problem Description

Every piece of equipment has its own service life or lifespan, regardless of whether it is officially specified or not. The service life can be extended through proper maintenance, whereas inadequate maintenance can significantly shorten it. This is also the case with infantry weapons used by the military. The initial velocity of a projectile depends on the age of the barrel, its maintenance, and the

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type of ammunition used. It is reasonable to assume that newly manufactured weapons have better performance characteristics than weapons that have been in service for many years. Different weapon systems and calibers exhibit certain positive and negative characteristics, depending on their service life and the length of time they have remained in service within the armed forces. Although drones are increasingly gaining prominence, rifles, pistols, and mortars continue to be used by infantry units as both individual and crew-served weapons.



Figure 1.Garmin Xero C1 Pro Chronograph.

Modern devices for measuring projectile velocity are now widely available to the general public. Therefore, in cooperation with the Department of Tactics and the Department of Military Mechanical Engineering at the Military Academy, the idea emerged to measure the initial velocities of projectiles from various infantry weapons with different designs, operating principles, and calibers. The initial projectile velocities were measured using the Garmin Xero C1 Pro Chronograph radar (Figure 1), which has demonstrated excellent performance for military applications. In addition to being commercially available to the general public, the device is also used for military purposes at the Department of Military Mechanical Engineering for the purpose described above.

The Garmin Xero C1 Pro Chronograph is a compact radar-based ballistic chronograph designed to measure projectile velocity. It is primarily used to determine the muzzle velocity of projectiles fired from various types of firearms and ammunition, making it suitable for ballistic testing, weapon performance evaluation, and comparative analysis of projectile velocity.

The Garmin Xero C1 Pro Chronograph is described in the user manual, as well as on the internet, as a lightweight device designed to measure the muzzle velocity of weapon projectiles.

Its total weight is 161 g, including the tripod. It has a built-in battery that can be recharged via a USB-C port. When fully charged, it enables the measurement of up to 2,000 projectile velocities or provides up to 6 hours of operation. It measures projectile velocities ranging from 30.5 to 1.524 m/s. It is suitable for military, law enforcement, and civilian applications, including sport shooting and hunting. It is rain-resistant and very easy to use, with the option of wireless connectivity to a smartphone or computer.

Through the same experiment (Table 1) were collected for the infantry weapons.

Table 1. Muzzle velocities of projectiles and standard deviations.

Type of weapon	Measured muzzle velocity (m/s)			Standard deviations	Number of projectiles	Air temperature (° C)	Measurement date
	min	mean	max				
12,7x108 mm M93 Long-range Sniper Rifle	806.8	820.2	835.5	7.3	14	21	May 5, 2026
7,9x57 mm M76 Sniper Rifle	715.5	724.5	736.7	4.9	27	22	May 15, 2026
7,62x54R mm M84 Machine Gun	743.2	764	789.9	7.5	45	21	May 14, 2026
5,56x45 mm M21Assault Rifle	856	888.8	914	13.2	35	20	May 13, 2026
7,62x39 mm M19 Modular Assault Rifle	698	711.6	721.3	6	39	21	May 14, 2026
9x19 mm CZ99 Pistol	336.8	346.7	355.4	3.9	40	20	May 13, 2026

Using the Garmin radar, an experiment was conducted during the firing exercise in which the radar detected a certain number of projectiles at different dates and under different temperature conditions, as shown in Figure 1. The standard deviations of the measured muzzle velocities of the projectiles are also presented.

Table 2 presents the types of ammunition used, as well as the muzzle velocities of the projectiles prescribed by the relevant regulations under ideal conditions, i.e., at a temperature of 15 °C and an atmospheric pressure of 1000 mb. The same table also presents the average barrel ages and the number of rounds fired from each barrel. The data presented in Table 2 were obtained from the relevant regulations for the weapons used in the firing exercise and from the technical documentation of the weapons. The data from Table 1, obtained experimentally, together with the data from Table 2, will be used to define the criteria for ranking infantry weapons, as determined by experts in the fields of mechanical engineering and military sciences from the Military Academy.

Since the weapons under consideration differ in their operating principles, intended purposes, mechanism and

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barrel designs, as well as in caliber, it is logical to use values representing the deviations of the experimentally obtained results from the expected and reference values. Modern weapons with new barrels generally exhibit smaller deviations; however, weapons that have fired a large number of rounds should not be disregarded, as high service life is also a desirable characteristic of modern weapons. The modular rifle has a specified barrel service life of 8,000 rounds fired, whereas the service life of other barrels depends on their maintenance and overall condition. Therefore, the effectiveness of the calibers and ammunition, as well as the type of weapon, were not taken into consideration. These aspects are discussed in the studies by [45, 46].

Table 2.Ammunition used and barrel condition.

Type of weapon	Ammunition	Tabulated muzzle velocity	Average barrel age	Average barrel corrosion	Rounds fired from the barrel
		m/s	Year	%	Quantity
12,7x108 mm M93 Long-range Sniper Rifle	12,7 mm SnR projectile M09	820	21	0	750
7,92x57 mm M76 Sniper Rifle	projectile M75	730	35	35	2 500
7,62x54R mm M84 Machine Gun	heavy projectile M30(J)	825	31	5	8 000
5,56x45 mm M21Assault Rifle	projectile M03	914	17	0	2 250
7,62x39 mm M19 Modular Assault Rifle	projectile M67	720	1	0	100
9*19 mm CZ99 Pistol	projectile M02 106-AJ	350	12	0	3 300

The 5.56 mm M21 assault rifle showed the greatest deviation in projectile muzzle velocity from the tabulated values. In contrast, the 7.62 mm M84 machine gun, one of the weapons that has been in service for a long period and has fired a large number of rounds through its barrel, demonstrated exceptionally good performance, even though ammunition with a heavy projectile was used, which has a mass 2 g greater than that of a standard projectile (which is difficult to find in any textbook and has also been experimentally verified for 9 g and 11 g). The 7.9 mm M76 sniper rifle has a considerably corroded barrel but still demonstrated good projectile performance due to the barrel manufacturing technology, as its barrel is not chrome-lined, unlike those of the other alternatives.

In order to obtain valid results, it is necessary to consistently follow the model scheme (Figure 2).

A detailed explanation of Figure 2, organized by phases and steps, can be presented and described using the following pseudocode:

Algorithm 1. CRITIC–MARCOS model with sensitivity and comparative analyses

Input: Alternatives (A={A_1,A_2,A_3,A_4,A_5,A_6}), criteria (C={C_1,C_2,C_3,C_4,C_5,C_6}), and decision matrix (X=[x_{ij}]_{6\times6}).

Output: Criterion weights (W), initial ranking (R_0), most favorable alternative (A^*), sensitivity analysis results, and comparative analysis results.

BEGIN

Phase 1: Calculation of criterion weights

1. Define criteria (C_1,C_2,C_3,C_4,C_5,C_6) based on expert assessment.
2. Define alternatives (A_1,A_2,A_3,A_4,A_5,A_6).
3. Construct the decision matrix (X=[x_{ij}]{6\times6}), where (x{ij}) represents the performance of alternative (A_i) with respect to criterion (C_j).
4. Apply the CRITIC method to calculate the objective criterion weights (W={w_1,w_2,w_3,w_4,w_5,w_6}).

Phase 2: Ranking of alternatives

5. Apply the MARCOS method using decision matrix (X) and criterion weights (W).
6. Calculate the utility functions of alternatives (A_1,A_2,A_3,A_4,A_5,A_6).
7. Rank the alternatives in descending order of their final utility values.
8. Determine the initial ranking (R_0).
9. Select the most favorable alternative (A^*).

Phase 3: Sensitivity analysis

10. Identify the criterion (C_k) with the highest weight (w_k=\max(W)).
11. Define weight-reduction scenarios for criterion (C_k).
12. Generate sensitivity scenarios using Monte Carlo simulation.
13. For each scenario, reduce the weight of criterion (C_k) according to the predefined reduction level.
14. Adjust the remaining criterion weights according to the adopted normalization procedure so that (\sum_{j=1}^{6}w_j=1).
15. Recalculate the rankings of alternatives (A_1,A_2,A_3,A_4,A_5,A_6) using MARCOS for each scenario.
16. Compare each scenario ranking with the initial ranking (R_0).
17. Evaluate ranking stability using an appropriate rank correlation coefficient.

Phase 4: Comparative analysis

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18. Apply TOPSIS, SAW, MAIRCA, and MABAC to rank alternatives (A_1,A_2,A_3,A_4,A_5,A_6).

19. Compare the rankings obtained using these methods with the initial MARCOS ranking (R_0).

20. Analyze the similarities and differences between the resulting rankings.

RETURN (W,R_0,A^*), sensitivity analysis results, and comparative analysis results.

END

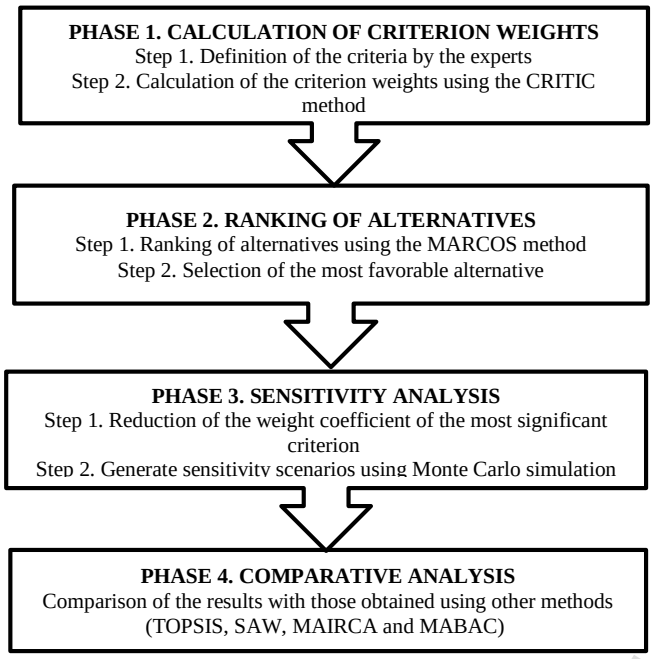


Figure 2.Graphical representation of the application of the CRITIC – MARCOS model.

Based on the experimental results, the question arises as to which weapon is the most favorable in terms of barrel condition and the measured projectile muzzle velocities relative to the values specified in the relevant manual.

2.2. Description of the Applied Methods

The paper will employ a hybrid model consisting of the CRITIC and MARCOS methods. The objective CRITIC method will be used to determine the criteria weighting coefficients, while the MARCOS method will be applied to rank the alternatives and select the most favorable one among the six alternatives for which the experiment was conducted.

2.2.1. Description of CRITIC (CRiteria Importance Through Intercriteria Correlation) Method

The CRITIC method is particularly useful in complex decision environments where subjective weighting is either infeasible or unreliable. It allows analysts to derive criterion weights based solely on the underlying structure of data, enhancing objectivity and reproducibility [47-49]. In addition to being explained and discussed in the Encyclopedia of Multi-Attribute Decision Making, it has also been used by numerous authors in the natural and social sciences, including the following authors [50,51].

The main advantage of the CRITIC method lies in its objective determination of criteria weights based on the information contained in the decision matrix. By simultaneously considering the contrast intensity of individual criteria, expressed through their standard deviations, and the correlations between criteria, the method accounts for both the discriminatory power of the criteria and the redundancy of the information they provide. This reduces reliance on subjective expert assessments and enables a more systematic determination of the relative importance of criteria. Furthermore, the CRITIC method can be integrated with various multi-criteria decision-making methods to rank alternatives. These characteristics make it suitable for evaluating experimental data and comparing weapons systems based on multiple quantitative criteria. [52].

The steps of the CRITIC method are as follows:

Step 1. Construction of the normalized decision matrix

Let X = [x *ij*] be the original decision matrix where *i = 1, 2, …, m* alternatives and *j = 1, 2, …, n* criteria. The matrix is normalized to ensure comparability among different scales. For a benefit-type criterion, normalization is performed as:

$$r_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

For a cost-type criterion, the formula is:

$$r_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

The resulting matrix R = [r *ij*] is the normalized decision matrix.

Step 2. Calculation of standard deviations

For each criterion j, the standard deviation σj of the normalized values is computed:

$$\sigma j = \sqrt{\frac{1}{m}\sum_{i=1}^{n}\left(r_{ij} - \bar{r}_j\right)^2} \quad (3)$$

where $\bar{r}_j$ is the mean value of the normalized values for criterion *j*. The standard deviation indicates the contrast intensity, reflecting the discriminating power of each criterion.

Step 3. Correlation and conflict matrix

The correlation coefficient r_{jk} is calculated between every pair of criteria *j* and *k* using Pearson's correlation:

$$r_{jk} = \frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)(r_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2 \sum_{i=1}^{m}(r_{ik} - \bar{r}_k)^2}} \quad (4)$$

The conflict between criteria is computed as:

$cjk = 1 - rjk$, $cjj = 0$ (5)

A higher c_{jk} value indicates greater disagreement (conflict) between criteria *j* and *k*.

Step 4. Computation of the information content (C*j*)

The information content of each criterion j is calculated as:

$$Cj = a_j \sum_{k=1}^{n}(1 - r_{jk}) \quad (6)$$

This step integrates both contrast intensity and intercriteria conflict, effectively capturing the importance of a criterion from a systemic perspective.

Step 5. Determination of criteria weights

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The normalized importance values (weights) of each criterion are determined by:

$$w_j = \frac{\mathrm{C}j}{\sum_{j=1}^{n} \mathrm{C}j}\ ,\ \sum_{j=1}^{n} w_j = 1 \qquad (7)$$

These weights wj are then used in subsequent decision-making models or utility-based ranking.All methods should be described in a logical order. Previously published methods may be referenced, but any modifications must be clearly explained.

2.2.2. Description of MARCOS (Measurement Alternatives and Ranking According to Compromise Sotution) Method

Measurement Alternatives and Ranking According to Compromise Sotution method calculates utility functions based on defining the level of closeness or distance between ideal and antiideal variants, and their compromise solution.

The main advantages of the MARCOS method lie in its systematic evaluation of alternatives relative to both ideal and anti-ideal solutions. This approach enables a comprehensive assessment of the relative performance of alternatives by considering their distance from the best and worst reference values. The method incorporates the weights of the evaluation criteria and accommodates both benefit and cost criteria, thereby facilitating the evaluation of alternatives with different performance characteristics. Furthermore, its structured computational procedure supports transparent decision-making and allows integration with objective weighting methods, such as CRITIC. The robustness of the resulting ranking can also be examined through sensitivity analysis by varying the criteria weights and observing changes in the ranking order. These features make MARCOS suitable for multi-criteria evaluation and ranking of technical systems based on experimental data.

It was first applied by [53] and consists of the following steps:

Step 1. Development of the initial decision matrix with multiple criteria (n) and variants (m).

Step 2. In this step, the user should perform extension of the initial matrix with the ideal (AI) and antiideal (AAI) solutions.

$$X = \begin{array}{c} \\ AAI \\ A_1 \\ A_2 \\ \cdots \\ A_m \\ A_i \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \cdots & x_{aan} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{22} & \cdots & x_{mn} \\ x_{ai1} & x_{ai2} & \cdots & x_{ain} \end{bmatrix} \end{array} \qquad (8)$$

The AAI is the worst value among the considered variants, depending on the type of criteria, while the AI is the best value, and it has been defined using the Eqs. (9–10):

$$\mathrm{AAI} = \min x_{ij} \text{ if } j \in B \text{ and } \mathrm{AAI} = \max x_{ij} \text{ if } j \in C \quad (9)$$

$$\mathrm{AI} = \max x_{ij} \text{ if } j \in B \text{ and } \mathrm{AI} = \min x_{ij} \text{ if } j \in C \quad (10)$$

The benefit set of criteria is marked with B, while the cost is marked with C.

Step 3. Calculate normalized matrix N by applying the following expressions:

$$n_{ij} = \frac{x_{ai}}{x_{ij}}\ ,\ if\ n_{ij} \in C_j \qquad (11)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}}\ ,\ if\ n_{ij} \in B_j \qquad (12)$$

Step 4. Determination of the weighted matrix V, where the previous matrix needs to be weighed with the criteria weights:

$$v_{ij} = n_{ij} \times w_j \qquad (13)$$

Step 5. Perform the procedure of calculation of the utility degree of the variant K_i, which has been related to AAI and AI.

$$K^-{}_i = \frac{S_i}{S_{aai}} \qquad (14)$$

$$K^+{}_i = \frac{S_i}{S_{ai}} \qquad (15)$$

Where S*i* (*i* = 1, 2, …, m) is the sum of the elements of the weighted matrix V:

$$Si = \sum_{i=1}^{n} v_{ij} \qquad (16)$$

Step 6. Computation of the utility function of the alternative f (Ki), which is a compromise of the observed variant in relation to the AI and AAI solution.

$$f(K_i) = \frac{K^+{}_i + K^-{}_i}{1 + \frac{1-f(K^+{}_i)}{f(K^+{}_i)} + \frac{1-f(K^-{}_i)}{f(K^-{}_i)}} \qquad (17)$$

Where f ($K^-{}_i$) is the utility function relative to the AAI solution, and f ($K^+{}_i$) is the utility function relative to the AI solution:

$$f(K^-{}_i) = \frac{K^+{}_i}{K^+{}_i + K^-{}_i} \qquad (18)$$

$$f(K^+{}_i) = \frac{K^-{}_i}{K^+{}_i + K^-{}_i} \qquad (19)$$

Step 7. Perform rank of variants according to their values.

2.2.3. Description of alternatives and criteria

Multi-criteria decision-making was carried out for six alternatives that will be selected according to six criteria proposed by experts:

Alternative 1 – The 12.7x108 mm M93 Long-range Sniper Rifle is intended for the destruction of important individual targets at greater distances. Basic data on 12.7 mm long-range rifles can be found in [54]. The best results when engaging personnel and unarmored vehicles are achieved at distances of up to 1 400 m. For lightly armored combat vehicles, effective engagement can be achieved at distances of up to 800 m. The rifle is fed from a 5-round magazine. The combat rate of fire is 8 to 10 rounds per minute. The reference muzzle velocity is approximately 820 m/s.

Alternative 2 – The 7,9x57 mm M76 Sniper Rifle is intended for engaging important individual exposed and concealed personnel targets at extended ranges. The rifle is fed from a 30-round magazine. The combat rate of fire is 30 rounds per minute. The reference muzzle velocity is approximately 730 m/s. It can be found in [55].

Alternative 3 – The 7,62x54R mm M84 Machine Gun is intended for neutralization and destruction of enemy personnel and weapons; destruction and disabling of motor

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vehicles and lightly armored vehicles, as well as targets in the airspace. Effective engagement: against ground targets at ranges of up to 800 m (up to 1 000 m with optical sights), against targets in the airspace at ranges of up to 500 m, and with concentrated fire at ranges of up to 1 000 m. Rate of fire is approximately 250 rounds/min under combat conditions. It can be found in [56].The reference muzzle velocity is approximately 825 m/s.

Alternative 4 – The 5,56x45 mm M21 Automatic Rifle is intended for Engagement of unprotected targets and targets protected by ballistic vests at ranges of up to 500 m. The under-barrel grenade launcher can be effectively used to engage lightly armored combat and non-combat vehicles, as well as to provide smoke screening and battlefield illumination. The best results are achieved with: single shots: 400 m; short bursts: 300 m; long bursts: 200 m and concentrated fire: 600 m. The reference muzzle velocity is approximately 914 m/s. It can be found in [57].

Alternative 5 – The 7.62x39 mm M19 Modular Automatic Rifle chambered for ammunition is intended for engaging individual and group targets at ranges of up to 500 m. When using the front and rear mechanical sights, the best results when engaging personnel targets are achieved with single shots at ranges of up to 400 m, short bursts at ranges of up to 300 m, and long bursts at ranges of up to 200 m. Concentrated fire by multiple shooters can be successfully employed against exposed and group targets at ranges of up to 600 m. Targets in the airspace can be successfully engaged at ranges of up to 500 m. The standard sight for the rifle is the M20 optical sight. The aforementioned data can be found in the [58], while the muzzle velocity of the projectile is given in the technical manual for the weapon and is 720 m/s.

Alternative 6 – The 9x19mm CZ99 Pistol is intended for engaging personnel targets at ranges of up to 50 m. The most effective engagement is achieved at ranges of up to 30 m. The pistol is a semi-automatic weapon, with single-shot firing. It is fed from a 15-round magazine. The rate of fire is 30–45 rounds per minute. The mass with a full magazine is 1145 g. The maximum range of the projectile is 1 600 m. The muzzle velocity of the projectile is 350 m/s [59].

In the first phase of the model, the potential criteria that influence the selection of the best alternative, i.e., the most optimal weapon, were defined. Given the complexity of defining and selecting the criteria, considering that the weapons under consideration differ in terms of their intended purpose, design, and operating principle, experts from the Military Academy were engaged. Some of the criteria were derived from the results of experimental testing, while others were obtained from the technical documentation of the weapons under consideration. For the problem under consideration, the experts identified six criteria, one of which is of the maximization type, while the remaining criteria are of the minimization type. The values for three criteria were derived from the experimental results, while the values for the remaining three criteria were obtained from the technical documentation of the weapons used in the tests.

Criterion C1 – Deviation from the reference muzzle velocity. This criterion was established based on the experimental results obtained using the GARMIN radar. The criterion was obtained as the deviation of the measured mean muzzle velocity of the projectile from the reference value specified in the regulations. This criterion depends on numerous factors, including the type of ammunition, barrel condition, and microclimatic conditions. A lower value is preferable, as the criterion is of the minimization - Cost type.

Criterion C2 – Standard deviation. This criterion was established based on the experimental results obtained using the GARMIN radar. The data were obtained directly from the radar and refer to the deviations in projectile velocities from one projectile to another. If all projectiles exhibit approximately the same deviation from the mean velocity, the value of this criterion is lower. This criterion is also of the cost, i.e., minimization, type.

Criterion C3 – Barrel age. It is desirable for the coefficient of variation (CV) to be as low as possible, as this indicates more consistent projectile velocities. In addition, newer barrels are generally associated with lower levels of corrosion. The barrel construction differs among the various weapons considered; some barrels are chrome-lined and reinforced, whereas others are not and are therefore more susceptible to corrosion and degradation resulting from inadequate maintenance and storage under field conditions. Except for the M19 modular automatic rifle, for which a barrel service life of up to 8 000 rounds is specified, no such limitation is defined for the other weapons considered. This criterion is also of the cost, i.e., minimization, type.

Criterion C4 – Barrel pitting. This criterion is directly related to the previous one, and therefore all the considerations stated above also apply to it. Although the CRITIC method did not assign this criterion the highest weight, the lowest-ranked weapon has the highest degree of barrel corrosion, which contributed to its last-place ranking. As the barrel ages, and particularly when it is not chrome-lined, the degree of corrosion increases. Barrel corrosion is expressed as a percentage: a new barrel has 0% corrosion, and the corrosion level increases over time. When it approaches 50%, the weapon is sent for overhaul. The experiment showed that, despite the presence of barrel corrosion, the muzzle velocity remained stable, owing to the high quality of the ammunition. In order to enable the application of the MARCOS method in cases involving a value of zero, a value of 1 was assigned to new barrels with a corrosion level of 0%. This adjustment is considered negligible because the corrosion level is recorded in 5% increments, while weapons with a barrel corrosion level exceeding 50% are considered unserviceable and are withdrawn from use for overhaul. This criterion is also of the cost, i.e., minimization, type.

Criterion C5 – Number of rounds fired. The data for this criterion were obtained from the technical documentation of the weapons. This criterion is of the cost, or minimization, type, because it is desirable for the barrel to fire a smaller number of rounds, thereby preserving the barrel and maintaining it in a stable and serviceable condition for further use. For none of the weapons considered is a maximum rate of fire specifically prescribed to prevent barrel overheating and potential damage. Proper use of the weapons assumes that the theoretical rate of fire specified in the relevant regulations and instructions is not exceeded. The CRITIC method identified this criterion as the most important criterion, which is consistent with its practical significance.

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Criterion C6 – Measurement Stability Coefficient (MSC). This coefficient represents the ratio between the number of projectiles fired (n) and the standard deviation (SD) of the measured muzzle velocities. It is calculated as follows:

$$MSC = n / SD$$

A higher value of this coefficient indicates that a larger number of projectiles was measured while the variability of the measured muzzle velocities was lower, which reflects greater measurement stability. The muzzle velocity was not measured for the same number of projectiles for each weapon, as shown in Table 1. The higher the number of projectiles for which the muzzle velocity was measured using the GARMIN chronograph, and the more uniform the measured velocities were, the higher the value of this coefficient, indicating greater measurement stability. This coefficient is of the benefit type, and it is desirable for it to have the highest possible value.

3. Results

3.1. Calculation of criteria weight coefficients using the CRITIC method

By applying the CRITIC method, the determination of the criteria weight coefficients was carried out according to the given steps (Table 3).

Table 3. Initial decision matrix.

	C1 cos	C2 cos	C3 cos	C4 cos	C5 cos	C6 ben
A1	0.2	7.3	21	0	750	1.9
A2	5.5	4.9	35	35	2500	5.5
A3	61	7.5	31	5	8000	8.7
A4	25.2	13.2	17	0	2250	2.6
A5	8.4	6	1	0	100	6.5
A6	3.3	3.9	12	0	3300	10.2

In the first step, by applying (Equations (1) and (2)), the normalized decision matrix (Table 4) is obtained.

Table 4. Normalized decision matrix.

	C1	C2	C3	C4	C5	C6
A1	1	0.634	0.412	1	0.082	1
A2	0.913	0.892	0	0	0.304	0.569
A3	0	0.613	0.118	0.857	1	0.191
A4	0.589	0	0.529	1	0.272	0.912
A5	0.865	0.774	1	1	0	0.45
A6	0.949	1	0.676	1	0.405	0

In the second step, by applying (Equation (3)), the standard deviation of the criteria weights for each column is calculated (Table 5).

Table 5. Standard deviation.

	C1	C2	C3	C4	C5	C6
SD	0.381	0.352	0.367	0.401	0.354	0.392

In the next step, by applying (Equation (4) and (5)), the linear correlation coefficient matrix is obtained (Table 6).

Table 6. Inverse linear correlation coefficient matrix.

	C1	C2	C3	C4	C5	C6
C1	0	0.623	0.624	1.119	1.860	1.732
C2	0.623	0	1	1.332	1.007	1.620
C3	0.624	1	0	0.315	1.570	1.078
C4	1.119	1.332	0.315	0	1.076	1.002
C5	1.860	1.007	1.570	1.076	0	1.546
C6	1.732	0.620	0.078	1.002	0.546	0

In the fourth and fifth steps, by applying (Equations (6) and (7)), the so-called information content and the weighting coefficients (wj) are calculated (Table 7).

Table 7. Criteria weighting coefficients.

w1	w2	w3	w4	w5	w6
0.153	0.16	0.137	0.157	0.203	0.19

Table 7 shows that (w5) is the most significant criterion, whereas (w2) is the least significant. However, the differences in the weighting coefficients are not particularly pronounced. The next step involves calculating the most favorable alternative.

3.2. Ranking of alternatives using the MARCOS method

MARCOS method is based on comparing the alternatives with the ideal (AI) and anti-ideal (AAI) solutions, whereby the utility degree of each alternative is determined based on its performance with respect to the considered criteria and the corresponding criteria weights. The initial decision matrix for the MARCOS (Table 8). Compared with Table 3, the change concerns the C4 criterion, for which positive values were entered. This adjustment is a prerequisite for applying the MARCOS method and is consistent with the criterion definition described previously.

Table 8. Initial decision matrix.

	C1 cos	C2 cos	C3 cos	C4 cos	C5 cos	C6 ben
A1	0.2	7.3	21	1	750	1.9
A2	5.5	4.9	35	35	2500	5.5
A3	61	7.5	31	5	8000	8.7
A4	25.2	13.2	17	1	2250	2.6
A5	8.4	6	1	1	100	6.5
A6	3.3	3.9	12	1	3300	10.2

By applying (Equations (9) and (10)), the normalized matrix and the ideal and anti-ideal alternatives are obtained (Table 9), in accordance with (Equation (8)).

Table 9. Normalized decision matrix.

	C1	C2	C3	C4	C5	C6
AAI	0.003	0.295	0.029	0.029	0.013	0.187

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A1	1	0.534	0.048	1	0.133	0.187
A2	0.036	0.796	0.029	0.029	0.040	0.537
A3	0.003	052	0.032	0.2	0.013	0.845
A4	0.008	0.295	0.059	1	0.044	0.259
A5	0.024	0.65	1	1	1	0.634
A6	0.061	1	0.083	1	0.03	1
AI	1	1	1	1	1	1

By multiplying the matrix elements by the corresponding criteria weight coefficients, using (Equations (11), (12), and (13)), the weighted normalized matrix is obtained (Table 10).

Table 10. Weighted normalized matrix.

AAI	0.001	0.047	0.004	0.005	0.003	0.036
A1	0.154	0.085	0.007	0.158	0.027	0.036
A2	0.006	0.127	0.004	0.005	0.008	0.102
A3	0.001	0.083	0.004	0.032	0.003	0.161
A4	0.001	0.047	0.008	0.158	0.009	0.049
A5	0.004	0.104	0.137	0.158	0.202	0.121
A6	0.009	0.159	0.011	0.158	0.006	0.19
AI	0.154	0.159	0.137	0.158	0.202	0.19

By applying (Equations (14)–(19)), the deviations from the ideal and anti-ideal solutions are calculated, resulting in the ranking of the alternatives (Table 11).

Table 11. Ranking results obtained using the MARCOS method.

	Ki-	**Ki+**	**fKi-**	**fKi+**	**fKi**	**RANK**
A1	4.95	0.466	0.086	0.914	0.462	3
A2	2.668	0.251	0.086	0.914	0.249	6
A3	3.004	0.283	0.086	0.914	0.280	4
A4	2.898	0.273	0.086	0.914	0.271	5
A5	7.7	0.725	0.086	0.914	0.719	1
A6	5.681	0.535	0.086	0.914	0.53	2

The top-ranked alternative is A5, the M19 7.62×39 mm Modular Assault Rifle, the newest weapon, with a low number of rounds fired and a new barrel. The presented ranking model places alternative A2 in the last position the M76 7.9×57 mm Sniper Rifle, with a severely damaged barrel that is not chrome-plated, while the weapon itself is of an older production date. The penultimate position was occupied by a relatively modern weapon, while the pistol ranked second.

3.3. Sensitivity analysis

An important segment of the multi-criteria decision-making model is the sensitivity analysis [60, 61]. It can be verified in several ways. One of the most commonly used approaches is the gradual reduction of the weight coefficient according to different scenarios. At the same time, in each scenario, the reduced value is evenly distributed among the other criteria. The ranking of alternatives is monitored in each scenario. If the top-ranked alternative remains among the highest-ranked even after the most significant criterion is removed, this is evidence that the model is stable. In this case, the weight coefficient w_5 was reduced by 5%, i.e., by 0.01 per scenario, and one-quarter of it, 0.002, was added to the other criteria weights. All scenarios, the top-ranked alternative remains A5, indicating that the model is stable. A graphical representation (Figure 3).

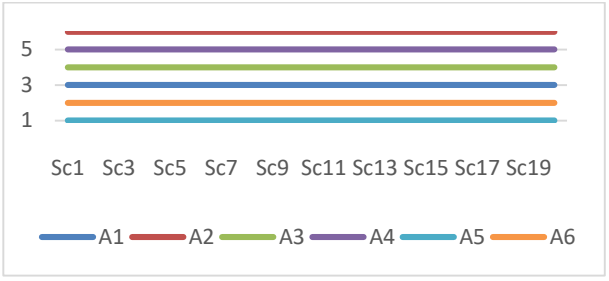


Figure 3. Graphical representation of changes in rankings across scenarios.

Based on Figure 3, it can be concluded that the model is highly stable. Even when the most significant criterion is excluded, w6 becomes the most significant criterion, while the ranking of the alternatives remains unchanged.

Sensitivity analysis was conducted using Monte Carlo simulation to assess the robustness of the initial ranking of alternatives obtained using the CRITIC–MARCOS model. The initial criterion weights were subjected to random relative variations within the ranges of ±5%, ±10%, and ±20%. In each simulation, new criterion weight values were generated and subsequently normalized so that their sum equaled unity. The MARCOS method was then recalculated using the resulting weights, while the decision matrix, set of alternatives, and criterion types were kept unchanged. Ranking stability was assessed based on the average rank of each alternative, the standard deviation of its rank, the frequency of attaining first place, and the degree of agreement between the simulated rankings and the initial ranking, measured using Spearman's rank correlation coefficient. Further details on the Monte Carlo simulation procedure can be found in [62-64].

A total of 10,000 simulations were performed for each of the three variation scenarios. In each simulation, new criterion weights were generated and normalized so that their sum equaled unity, after which the MARCOS calculations were repeated for all six alternatives. The results are presented in Table 12.

Table 12. Generate sensitivity scenarios using Monte Carlo simulation.

	Mean rank ±5%	**Rank SD ±5%**	**Mean rank ±10%**	**Rank SD ±10%**	**Mean rank ±20%**	**Rank SD ±20%**
A1	3	0	3	0	2.999	0.026
A2	6	0	5.988	0.107	5.832	0.374
A3	4.018	0.133	4.174	0.379	4.314	0.464
A4	4.982	0.133	4.837	0.399	4.854	0.679
A5	1	0	1	0	1	0
A6	2	0	2	0	2.001	0.026

The robustness of the proposed CRITIC–MARCOS model was assessed using Monte Carlo simulation with 10,000 iterations for each of three scenarios involving relative variations of ±5%, ±10%, and ±20% in the initial criterion weights. In each iteration, the randomly perturbed weights were normalized to sum to unity, and the MARCOS procedure was repeated while keeping the decision matrix and criterion types unchanged. The results indicated a high degree of ranking stability, with mean Spearman correlation coefficients of 0.9990, 0.9894, and 0.9724 for the three scenarios, respectively. The initial ranking was preserved in

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98.21%, 81.41%, and 51.79% of the simulations, respectively. Alternative A5 retained the first position in all simulations, demonstrating strong robustness with respect to variations in criterion weights. The greatest rank variability was observed for A4, reflecting its close initial utility value to that of A3. Overall, the findings indicate that the leading alternative is robust to substantial changes in criterion weights, although the relative positions of some lower-ranked alternatives are more sensitive to such variations.

3.4. Comparative analysis

Comparative analysis is indispensable in almost all multi-criteria decision-making studies, and one such study is [65]. To further verify the stability of the model and the ranking of the alternatives, the alternatives will be ranked using the same weighting coefficients by applying other Multi-Criteria Decision-Making methods, namely SAW (Simple Additive Weighting), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), MAIRCA (Multi-Attributive Ideal-Real Comparative Analysis) and MABAC (Multi-Attributive Border Approximation Area Comparison).

Table 13. Ranking results obtained using the different methods.

	MAR	TOP	SAW	MAI	MAB
A5	1	1	1	2	2
A6	2	3	2	1	1
A1	3	2	3	3	3
A3	4	6	6	6	6
A4	5	4	4	5	5
A2	6	5	5	4	4

The results of ranking the alternatives using the different methods (Figure 4).

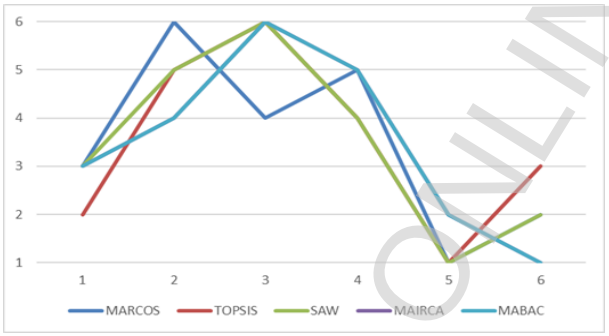


Figure 4. Ranking the alternatives using the different methods.

Table 13 and Figure 4 shows that all five methods produce similar rankings of the alternatives, indicating excellent ranking stability.

By applying Spearman's rank correlation coefficient to the rankings in the given scenarios relative to the initial scenario. The results shown in Figure 3 are obtained. The Spearman coefficient is calculated using the formula [66]:

$$S = 1 - \frac{6\sum_{i=1}^{n} D_i^2}{n(n^2-1)} \qquad (20)$$

where *Di* is the difference in ranks, and *n* is the number of alternatives.

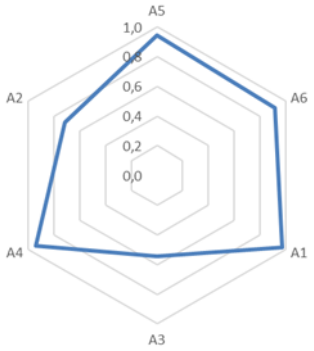


Figure 5. Spearman's rank correlation coefficient across methods.

Spearman's rank correlation coefficient between the rankings obtained by the other methods and the MARCOS method indicates a perfect correlation for alternative A1, with a coefficient of 1. For alternatives A4, A5, and A6, the coefficient is 0.9, indicating a very strong correlation of the rankings. For alternative A2, the coefficient is 0.7, which represents a strong correlation. In the case of alternative A3, the coefficient is 0.5, indicating a moderate correlation of the rankings.

4. Discussion

The CRITIC–MARCOS multi-criteria model identified A5, the M19 7.62×39 mm Modular Assault Rifle, as the best-ranked alternative. The 9×19 mm CZ99 pistol (A4) ranked second, followed by the 12.7×108 mm M93 long-range rifle (A3) in third place and the 7.62×54R mm M84 light machine gun (A6) in fourth place. The 5.56×45 mm M21 assault rifle (A1) ranked second-to-last, while the 7.9×57 mm M76 sniper rifle (A2) occupied the last position. The robustness of the proposed model was further examined through comparative analysis with the SAW, TOPSIS, MAIRCA, and MABAC methods. The results showed a high degree of agreement between the rankings, particularly for A5, which achieved first place in three of the five methods, and A1, whose ranking remained relatively stable across the methods. The Spearman rank correlation coefficients obtained in the sensitivity analysis of the CRITIC–MARCOS model were 1.0 for A1, 0.9 for A4, A5, and A6, 0.7 for A2, and 0.5 for A3. These results indicate that the ranking of most alternatives remained highly stable under variations in criterion weights, although A3 exhibited comparatively greater sensitivity. Furthermore, the removal of the criterion with the highest CRITIC weight (C5) resulted in C6 becoming the most influential criterion, while the final ranking remained unchanged. This finding provides additional evidence of the robustness of the proposed model and indicates that the leading position of A5 was not determined exclusively by a single criterion.

To further assess the consistency of the proposed CRITIC–MARCOS model, a comparative statistical analysis was conducted using the Spearman rank correlation coefficient. The MARCOS ranking was used as the reference for comparison with the TOPSIS, SAW, MAIRCA, and MABAC methods.

The Spearman correlation coefficients were 0.771 for TOPSIS, 0.829 for SAW, and 0.714 for both MAIRCA and MABAC. These results indicate positive associations between the rankings obtained using MARCOS and those

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generated by all four comparative methods. The highest agreement was observed between MARCOS and SAW. In contrast, TOPSIS, MAIRCA, and MABAC each yielded, indicating an average absolute rank difference of one position relative to MARCOS.

The results also reveal some differences in the ordering of individual alternatives. For example, A3 ranked fourth according to MARCOS but sixth according to all four comparative methods. Nevertheless, the maximum absolute difference between the ranks assigned by MARCOS and any of the comparative methods was two positions. Overall, the statistical indicators support the consistency of the proposed ranking in relation to established MCDM methods, while also identifying differences that warrant further discussion. Since the analysis includes only six alternatives, these findings should be interpreted as evidence of ranking agreement rather than conclusive proof of the model's absolute validity.

Comparative analysis (Figure 4) shows that alternative A5 is ranked first by three methods, while it is ranked second by the MAIRCA and MABAC methods, with A6 occupying the first position. On the other hand, according to the TOPSIS method, A5 is ranked third, while A1 occupies the first position. A1 is ranked third by all other methods, except TOPSIS. Therefore, it can be concluded that A2 occupies the first position; however, this result requires a more detailed analysis.

The difference (Figure 5) can be explained by the fact that A3 is ranked fourth according to the MARCOS method, whereas it is ranked last, i.e., sixth, according to the other methods. Therefore, despite the lower correlation coefficient for A3, the overall results indicate satisfactory stability of the proposed model. The application of this sensitivity analysis demonstrates that the model provides satisfactory results, with correlation coefficients ranging from moderate to perfect, and predominantly very strong correlations among the obtained rankings.

5. Conclusion

This study presents an experimental verification of reference projectile muzzle velocities and a ranking of infantry small arms using a multi-criteria approach that incorporates measured muzzle velocities and selected technical and operational characteristics of the weapons. The results reveal differences among the tested weapons, indicating that their positions in the ranking cannot be explained by a single indicator but depend on the combined influence of multiple criteria. This confirms the importance of integrating experimental results with data on weapon condition and service history when conducting comparative assessments.

The highest-ranked weapon is the 7.62/6.5 mm M19 Modular Rifle, which benefited from its favorable technical condition, the lowest number of rounds fired, and smaller deviations in the measured muzzle velocities of the 7.62 mm projectiles compared with the other tested weapons. The 7.9 mm M76 Sniper Rifle ranked last, with a measured barrel erosion of 35%. In addition, its barrel is not chrome-lined, and the rifle has fired a large number of rounds. Despite these characteristics, the measured projectile muzzle velocities remained satisfactory. This finding indicates that barrel condition and service history should be considered in a broader context, together with measured ballistic parameters, rather than as isolated indicators of overall weapon performance. This relationship could be investigated further in future research.

The scientific significance of this study lies in expanding knowledge of the possibilities for the objective comparative assessment and ranking of infantry small arms of different calibers, designs, and intended purposes, based on experimental measurements and relevant technical and operational indicators. A particular contribution is the integration of deviations between measured and reference projectile muzzle velocities, the variability of measured velocities, and data on barrel condition and the number of rounds fired into a unified assessment procedure. In this way, the study provides a basis for further investigations into the reliability of reference ballistic data and the improvement of weapon evaluation procedures under service conditions.

The practical significance of the study lies in the potential use of the results as an additional source of technical information for assessing weapon condition, planning maintenance, and making decisions regarding further testing and use. The proposed approach may also support the consideration of suitable weapons for specific tactical tasks by taking into account their technical characteristics and experimental test results. Nevertheless, the final selection of a weapon for a particular purpose should also account for other relevant factors, including tactical requirements, reliability, ergonomics, effectiveness, and operating conditions.

One of the limitations of the proposed CRITIC–MARCOS model is that the reliability of the results depends on the quality and representativeness of the experimental data, as well as on the selection of the evaluation criteria. Furthermore, although the model enables the ranking of alternatives based on predefined criteria, it does not independently explain all the factors responsible for deviations between reference and experimentally measured projectile muzzle velocities. Factors not explicitly included in the model, such as ammunition characteristics, test conditions, and weapon design specifications, may also influence the final ranking.

Future research should focus on ranking small arms of the same type and intended purpose, such as pistols or assault rifles, based on the experimental verification of projectile muzzle velocities using the proposed CRITIC–MARCOS model or other multi-criteria decision-making approaches. Further investigations should also assess hit accuracy under comparable firing conditions, particularly for similar weapons tested at identical ranges, to examine the relationship between muzzle-velocity consistency and achieved accuracy. In addition, applying alternative methods for determining criterion weights and ranking alternatives would enable further verification of the robustness of the results. Expanding the analysis to include a larger number of weapons, different barrel conditions, and varying service conditions could further improve the reliability of the assessment and the practical applicability of the proposed approach.

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Primena CRITIC–MARCOS modela za rangiranje pešadijskog naoružanja na osnovu eksperimentalno određenih početnih brzina projektila

Originalni naučni rad, operaciona istraživanja, mašinstvo, matematika

Ključne reči:
pešadijsko naoružanje;
početna brzina;
GARMIN radar:
CRITIC;
MARCOS

Apstrakt

Pozadina/Cilj: Cilj istraživanja je rangiranje pešadijskog naoružanja primenom višekriterijumskog modela CRITIC–MARCOS, na osnovu eksperimentalno određenih početnih brzina projektila i procene stanja cevi oružja. Referentne vrednosti početnih brzina projektila preuzete su iz odgovarajućih pravila i uputstava za naoružanje. Istraživanjem su obuhvaćeni sistemi različitih kalibara, namena i konstruktivnih karakteristika. Imajući u vidu njihove međusobne razlike, eksperti iz oblasti mašinstva i vojnih nauka definisali su šest kriterijuma koji omogućavaju objektivnije i metodološki utemeljeno poređenje naoružanja na osnovu eksperimentalnih rezultata merenja početnih brzina projektila i stanja cevi. **Metode:** Eksperimentalno određivanje početnih brzina projektila izvršeno je primenom hronografa Garmin Xero C1 Pro. Za određivanje težinskih koeficijenata definisanih kriterijuma primenjena je objektivna CRITIC metoda, dok je za rangiranje pešadijskog naoružanja, na osnovu utvrđenih težinskih koeficijenata i vrednosti kriterijuma, korišćena MARCOS metoda. Na kraju je sprovedena analiza osetljivosti predloženog modela i komparativna analiza rezultata sa sa drugim metodama, radi procene stabilnosti i pouzdanosti dobijenih rezultata rangiranja. **Rezultati:** Rezultati su pokazali odstupanja referentnih i izmerenih početnih brzina, zavisna od vrste naoružanja, kalibra i municije. Hromirane cevi pokazale su povoljnije performanse. CRITIC–MARCOS model najbolje je rangirao pušku M19 (7,62 mm), a najlošije snajpersku pušku M76 (7,9 mm). M93 (12,7 mm) zauzela je treće mesto uz najmanje odstupanje, CZ99 (9 mm) drugo, M84 (7,62 mm) četvrto, dok je M21 (5,56 mm) bila peta uz najveće odstupanje. **Zaključak:** Rangiranje pešadijskog naoružanja na osnovu eksperimentalno izmerenih početnih brzina projektila i stanja cevi, primenom predloženog modela CRITIC–MARCOS, ukazuje na njegov potencijal za objektivnu procenu i međusobno poređenje performansi različitih sistema naoružanja. Dobijeni rezultati mogu poslužiti kao osnova za unapređenje postupaka ispitivanja i procene tehničkog stanja naoružanja, kao i za planiranje budućih istraživanja usmerenih na detaljniju analizu pojedinačnih kategorija naoružanja, uz uvažavanje njihovih specifičnih konstruktivnih karakteristika i eksploatacionih uslova.

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