Selection of an airsoft rifle for urban combat using the hybrid multi-criteria decision-making model Borda-AHP-SAW and Entropy-CRITIC-FanMa-SAW

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Summary:

Introduction/purpose: The paper presents the application of multi-criteria decision-making methods in order to select an airsoft replica of an automatic rifle for practicing tactical actions in urban combat. First, experts ranked the criteria according to which alternatives would be selected. By applying the Borda and AHP methods, the weighting coefficients of the criteria were determined, and then the most favorable alternative was selected by applying the SAW method. The selection procedure was repeated when the selection was made without experts, but the weighting coefficients of the criteria were determined by the objective Entropy, CRITIC, and FanMa methods and a comparative analysis of the results was performed. The aim of the paper is to select the most effective airsoft rifle for professional and civilian use for practicing tactical actions and actions in urban combat by combining multi-criteria decision-making methods. Minimal resource consumption is always the starting point today, while ensuring the most efficient way to practice tactical actions that are as close as possible to real conditions.

Methods: For the first time, the method of determining the weighting coefficients of criteria using multidisciplinary methods of multi-criteria decision making on a specific problem in the field of tactics with weapons systems was shown with expert opinion, and then the results were compared when experts were not engaged. The experts in the field of Tactics and Weapons from the Military Academy first selected and ranked seven criteria. Then, their opinions were refined using the Borda method, and the results were entered into the AHP method to select the weighting coefficients of the criteria. Finally, the most favorable alternative was selected based on the SAW method. Since the above procedure for determining the weighting coefficients of the criteria was calculated for the first time by engaging experts in this way, the procedure for selecting the most favorable alternative was repeated without engaging experts, but the weights of the criteria were determined using objective methods and the results were compared through comparative analysis. The alternatives are five airsoft rifles with a hopup chamber, some of which are used at the Military Academy and in special army units for training in various combat-tactical actions, while in civilian life they are used by airsoft weapon enthusiasts.

Results: The most affordable airsoft rifle was chosen to provide minimum resource consumption with maximum performance and bring the greatest possible realism to combat situations when practicing tactical actions in urban environment.

Conclusion: The solution, with a comparative analysis of the results obtained in two ways, takes into account the simultaneous optimization of seven criteria which differ slightly, in order to select the most effective airsoft rifle for practicing tactical procedures in order to provide conditions that are closest to real combat situations at short distances.

Key words: airsoft rifle, selection, Borda, AHP, SAW, Entropy, CRITIC, FanMa method.

Introduction

With the advent of airsoft guns with adjustable hopup chambers that improve the flight characteristics of their projectiles, many "games" have replaced paintball weapons with the newly appeared ones. Paintball weapons rarely found their place in defense system units, except for some countries (Константинов & Шохирев, 2023), while the emergence of airsoft weapons has almost supplanted the use of classic weapons in military units (Lee et al, 2023) and police units (Martinez, 2008) for practicing certain tactical actions and playing out different situations in urban environments through different concepts (Dustin & Firmansyah, 2023; Putra et al, 2024; Lisboa & de Moraes, 2025), in closed spaces, underground installations, etc. In appearance, airsoft replicas are identical to classic weapons, and only good experts in weapons, at a closer distance of a few meters, can notice the differences, which is the goal of manufacturers of this type of weapon, regardless of the country of production (Menet & Szarucki, 2020).

There are many works in the literature on the selection of military equipment or fighters using multi-criteria decision making, for example, for: choosing an assault rifle, Radovanović et al, (2024); weapon selection, Dağdeviren et al, (2009); fighter optimal, Suo et al, (2025); framework for armed unmanned aerial vehicles, Keleş (2024); evaluating military tanks, Genc (2015); a multi-criteria decision-making approach for equipment evaluation, Guan et al, (2024); selection of vehicles, Araujo et al, (2023); selection of fighter aircraft, Rajurkar et al, (2023); optimising assault boat selection for military operations, Tešić et al, (2023a); weapon system selection, Dağıstanlı, (2025); and pontoon bridge selection, Tešić et al, (2023b). An analysis of domestic literature does not reveal many works on the topic of airsoft weapons, while in foreign literature there are studies not only about this type of weapon but also about injuries caused by it (Endo et al, 2001; Strong & Coady 2014; Pratama & Aryanto, 2024). The advantages of airsoft over paintball for civilian use and classic weapons for defensive use are many. Unlike with classic weapons, the shot is almost silent and can be used near settlements, while the use of maneuver ammunition for practicing tactical actions is generally prohibited near settlements and even in military and police facilities. The noise level generated by shooting airsoft weapons indoors is negligible and protects the hearing, unlike when firing a maneuver bullet. Maintaining airsoft weapons after using pellets is much simpler compared to using a dummy bullet with classic weapons and paint with paintball. There is less mass of ammunition and less environmental pollution from pellets compared to the combustion products of gunpowder and metal (mainly brass or copper) shells that are not removed after use, as well as paint from using paintball ammunition. Pellets are cheaper than dummy bullets and paintball ammunition and cause less damage to the walls of buildings and surrounding areas. Among the disadvantages, it can be noted that wearing glasses, a mask and gloves is mandatory, i.e. every part of the body must be covered and the player must be dressed in several layers regardless of the weather conditions - a pellet hit in the body through clothing if an individual is lightly dressed is extremely painful, depending on the characteristics of the weapon. For civilian use, the key difference between paintball and airsoft weapons is that airsoft weapon users must be morally responsible and admit to being hit by a pellet instead of suffer pain and immorally continue playing, while a paintball hit with colored ammunition is easily noticeable. While taking these features into consideration in a wide range of airsoft weapon manufacturers, it is necessary to choose the most favorable one for a particular situation in which it is intended to be used.

The aim of this research is to find the most optimal solution from the five airsoft rifles offered, taking into account the specifics of the scientific field of Military Sciences - Tactics with Weapon Systems, by applying the multi-criteria optimization method. The solution is based on the sublimation of the opinions of the Military Academy experts in this field, who use this type of weapon in the training of cadets. They do not know multi-criteria decision-making methods, since these experts are not expected to be knowledgeable about multi-criteria decision making. The proposed methodology was introduced with the idea of bringing decision making down to the lowest infantry level in the army, down to the department commander, with the aim of accepting and using it in various situations of decision making at the lowest level, not only in the selection of equipment. Based on the criteria defined by the experts, the alternatives were selected. After that, the criteria were ranked using the Borda method and the weighting coefficients of the criteria were determined using the AHP method. This method was chosen to avoid matrix inconsistency when comparing criteria in pairs and because the experts were not familiar with multi-criteria decision-making methods. Then, the ranking of the alternatives was carried out using the SAW method and the most optimal alternative was selected. Instead of the Borda method, any other method of counting ranks could have been used. The SAW method was chosen as the oldest and simplest method for ranking alternatives, while the use of other methods is a suggestion for future research. The applied method of determining the weighting coefficients of the criteria was determined in the above manner for the first time in a paper and requires verification. It was carried out by determining the weighting coefficients of the criteria using three objective methods: Entropy, CRITIC, and FanMa, included in the SAW method, and then a comparative analysis of the results was performed using Spearman's rank correlation coefficient.

Problem description

Simulators, airsoft weapons and the use of drones will play an enviable role in the training of military and police units in the future, as well as in many other areas of life and work. Jokić et al, (2025) describe the development of a decision support system in the process of training soldiers. Airsoft weapons are a simulator of classic weapons that can be owned by every citizen of the Republic of Serbia over the age of sixteen. Airsoft weapons are constantly developing, reaching initial bullet speeds that are similar to those of a classic pistol, which requires stricter legal regulations. These velocities of 6 mm bullets were provided by the development of a hopup chamber that can be easily adjusted by the user depending on the external temperature and the age of the replica, and high-quality electric motors located in the rifle handle. The hopup chamber ensures the movement of the bullet along an inverted parabola at distances of up to 100 m. Aiming is done based on muscle memory and by observing the course of the ball trajectory, and of course, mechanical or various optical sights can be used for certain distances, depending on the chamber settings. Durable and quickly rechargeable lithium-polymer Li-Po batteries, which are additional equipment, ensure long-term operation of the device in extreme conditions, while charging takes about ten minutes. All these are data - criteria that are difficult to obtain by the manufacturer, but can only be demonstrated based on experience and prolonged use of the rifle.

In order for the research to be conducted properly, it is necessary to implement each step and phase with sufficient attention so that the results are valid - Figure 1.

Available criteria from manufacturers include mass, price, length of the replica and the barrel, power of the replica, initial bullet velocity, magazine capacity and battery capacity, etc. These known and available criteria were taken into consideration for the research along with the opinion of experts in the field of tactics with weapon systems.

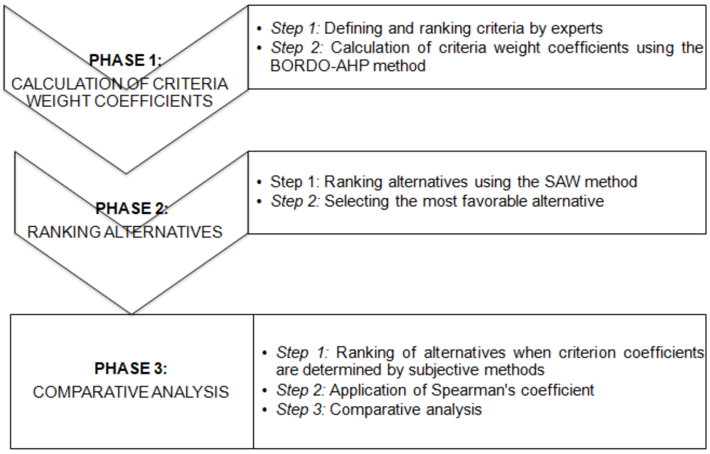

Figure 1- Phases and steps of the research

Hybrid multi-criteria decision-making models have already been applied in the field of military sciences, namely: Radovanović et al, (2023) DIBR-FUCOM-LMAW-Bonferroni-grey-EDAS model; Markatos & Pantelakis, (2023) holistic approach based on multi-criteria decision making for aircraft evaluation and comparison; Jokic et al, (2024) selection of calibers for weapons in the Serbian Army; Tešić et al, (2024) improvement of multi-criteria decision making using fuzzy logic; Ayvaz et al, (2024) integrated Fine-Kinney risk assessment model using Fermatean fuzzy AHP-WASPAS for occupational hazards in the aquaculture sector; Božanić et al, (2024) Fuzzy DIBR II-MABAC model for flood prevention; and Kress & MacKayetc (2025) Lanchester-type models for attritional warfare balance military casualties in two opposing forces.

Description of the methods used

The work will use the Borda group multi-criteria decision-making method, the AHP and SAW individual multi-criteria decision-making methods and the Entropy, CRITIC, and FanMa methods. The most sensitive part of the model is the definition of the weighting coefficients of the criteria, which is performed using the AHP method. There are a number of methods for defining the weighting coefficients of the criteria, which have certain advantages compared to the AHP method. Although the AHP method is one of the older methods of multi-criteria decision making, it has certain qualities that recommend it over others. The large number of criteria comparisons that exist in the AHP method, on the one hand, represents more laborious work for experts and analysts who process information, but on the other hand, it provides rich information from the comparison of criteria in pairs. In general, newer methods (such as BWM, LBWA, FUCOM, DIBR, and DIBR II) have a much smaller number of mutual comparisons of criteria, but they do not perform all mutual comparisons of criteria, but only a part. Considering that information is drawn from a smaller number of comparisons than when applying the AHP, it is also clear that the possibility of error in defining the weighting coefficients of the criteria in newer methods is much higher compared to the one involving the AHP. The mentioned, newer methods have defined techniques for checking consistency. That check is performed on the segment of pairwise comparisons, unlike with the AHP method where the consistency check is comprehensive.

Description of the Borda method of group reading

The Borda method is one of the oldest methods of group decision making, developed by the Frenchman Borda in 1781. It was widely used in the process of voting for the election of deputies in many countries of the world (Costa, 2017; Barberà et al, 2023; Saari, 2023). It can be used in its original form (Ilmiyah et al, 2023), and there are a number of modifications (Lin & Lin, 2023; Jones & Wilson, 2024; Biswas et al, 2025b). The basis of the method is to choose the alternative that in most cases was the first or tended to be the first one.

A matrix is formed in accordance with the rank of all decision makers, where the first column shows the rank of alternatives and the first row shows decision makers (Çalikoğlu & Łuczak, 2024). The second matrix is formed where the decision makers are in the left-wing column of the alternatives and in the first row, and the cells - fields of the matrix are filled by assigning the value 0 to the last ranked alternative for each decision maker, the second ranked alternative from the back the value 1 and the best placed alternative An the value n - 1. Finally, the vector W is obtained in the new right column where the values by rows are summarized. The best placed alternative - the most acceptable alternative is the one that has the highest value of the vector W.

Description of the AHP method

The Analytical Hierarchy Process method was developed by Thomas Saaty (1980). The method has undergone a large number of modifications, but in some cases it is still used in its original form both in individual and group decision making, Tešić et al, (2024), and is used in a large number of different decision-making cases. One of the most recent comprehensive surveys on recent modified and hybrid approaches to the AHP method can be read in Ashour & Mahdiyar (2024). Here, a modification will be presented for the first time, where instead of the classic Saaty scale, a scale derived from the Borda method is used.

A matrix with n rows and columns of criteria is formed and filled first along the unit diagonal because the criterion is compared with itself and then the newly introduced scale is used while respecting the filling below the diagonal based on the formula:

$$a_{ij} = 1 / a_{ji} \quad (1)$$

The value above the diagonal is filled while the opposite cell is the reciprocal of the filled value, otherwise the matrix will not be consistent. There are many works on modifications and scales of the AHP method, one of which is (Shageev, 2022). When filling the matrix from the upper side of the diagonal, the following should be observed - the value of the normalized initial vector from the Borda method is subtracted - from the criterion vector in the row, subtract the criterion vector in the column. In the case of a negative value, enter the reciprocal of the positive value using the formula:

$$- a_{ij} = 1 / a_{ij} \quad (2)$$

The next step is to sum the column values. A new matrix of n*n criteria is formed, the cells of which are filled as the quotient of the cell of the previous matrix with the divisor of the sum by type of the previous matrix. Finally, the columns are summed and the obtained values represent the weight coefficients of the criteria and their sum must be 1.

The next step is to calculate the consistency ratio of the CR matrix, which must be less than 0.1.

$$CR = CI / RI \quad (3)$$

where CI is the consistency index

$$CI = (\lambda max - n) / (n-1) \quad (4)$$

and RI is a random index according to Saaty and depends on the number of criteria and is taken from the table (in this case it is 4 criteria, i.e., 0.9); λmax is its own value which is calculated in accordance with the formula for each criterion

$$\lambda max = (Aw*w) / w*w \quad (5)$$

A is the criteria comparison matrix.

Table 1 – Random index by Saati

n	3	4	5	6	7	8	9	10
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The matrix is multiplied by the vector by multiplying W by each row-row cell and summing the products. If the consistency ratio (CR) is greater than 0.1, the criteria matrix is inconsistent and it is necessary to check the comparisons or change the method. The closer CR is to 0, the more consistent the matrix is, and one goes to the initial - main matrix.

Then the weighted sum is calculated for all alternatives, by multiplying the matrix by W. This is done by writing W below the alternatives and adding the product of the cells of the matrix and the vector W. In this way, the cells of the alternatives are joined. Again, the number of columns is 1. By comparing the numbers, the most favorable alternative is reached. The higher the value, the more acceptable the alternative.

The AHP method for ranking most often uses the Saaty scale. The scale used in the paper differs from the Saaty scale in that it is derived from counting the ranks of criteria ranked by experts. Therefore, the scale may have a larger or smaller interval than the Saaty scale, depending on the ranking of the criteria by experts and the number of experts. If all experts rate a criterion as the least important, the scale will have a large range. If all experts rate one criterion as the most important, the Borda method is unusable because the value of one criterion cannot be 0, nor can two criteria have the same rank. In these cases, the presented method is unusable. In order for the scale to start from 1, all criteria are divided by the weight of the criterion that is best ranked by experts. So the ratio of the best ranked criterion to the worst ranked criterion can vary within the limits of maximum d*c-1 where d is the number of experts and c is the number of criteria.

Description of the SAW method

Simple Additive Weighting is one of the oldest and simplest methods for ranking alternatives (Churchman & Ackoff, 1954). Many modern methods have found their footing in it, and the results obtained are approximately the same. It is used in both natural and social sciences in hybridization with another method to determine the weights of criteria. In scientific papers it has been compared with other methods or used independently (Lubis et al, 2021; Ciardiello & Genovese, 2023; Stević et al, 2024; Wang et al, 2024; Susilo & Wahyuni, 2024; Briscilla & Sundarrajan, 2024; Eti & Yüksel, 2024).

It is easy to use and in the first step gives the researcher the freedom to use any formula for normalizing the initial decision matrix. In this case, vector normalization was used according to the formulas for:

a) benefit criteria

$$n_{ij} = \frac{f_{ij}}{\sqrt{\sum_{i=1}^{m} f_{ij}^2}} \quad (6)$$

b) cost criteria

$$n_{ij} = 1 - \frac{f_{ij}}{\sqrt{\sum_{i=1}^{m} f_{ij}^2}} \quad (7)$$

where: f_{ij} – cell of the initial decision matrix; n_{ij} – normalized matrix cell; m – number of alternatives; j – number of criteria.

The next step is to weight the normalized matrix by multiplying each cell with a weighting coefficient for that criterion obtained by some other method.

$$o_{ij} = n_{ij} * w_i \quad (8)$$

Finally, in the third step, the cells are summed by type and the total weight value for each alternative is obtained. The sum of all alternative weights is 1. The most optimal alternative is the alternative with the highest sum value.

Description of the Entropy, CRITIC, and FanMa method

When the weighting coefficients of the criteria are determined based on the objective methods: Entropy (Srđević et al, 2003), CRITIC (Diakoulaki et al, 1995), and FanMa method (Srđević, 2005).

Entropy is a method that has been used in various forms since ancient times in natural sciences (Jaynes, 1982; Sakata & Sato, 1990). Since the beginning of this century, it has also appeared in many works in social sciences (Abbas, 2003, 2006; Sun et al, 2023; Basilio et al, 2023; Shanmugapriya et al, 2024; Ali et al, 2024). In social sciences, it is used to determine the weights of criteria in combination with other methods when ranking alternatives (Kizielewicz & Sałabun, 2025). It is based on the use of the natural logarithm ln. The calculation is the same for benefit and cost criteria (Žižović & Albijanić, 2025). The initial matrix has numerical values where the rows represent alternatives and the columns represent criteria (Biswas et al, 2025a). First, the decision matrix is normalized by filling the cells of the normalized matrix by dividing the cell of the initial matrix by the sum of the cells of the matrix by the columns-criteria. The next step is to calculate the entropy of the coefficient according to the formula:

$$e_j = -k\sum_{i=1}^{n} r_{ij} \ln r_{ij} \qquad (9)$$

where: e_j – entropy of the criterion coefficient, κ – coefficient obtained as the reciprocal of the natural logarithm of the number of alternatives, in this case ln 5; r_{ij} – normalized matrix cell, and n – number of alternatives. In the next step, the degree of divergence of the criteria is calculated by subtracting e_j. from 1. Finally, the divergence is normalized by dividing the divergence of one criterion by the sum of the divergences of all criteria, thus obtaining w_i. the weighting coefficient of the criterion.

CRITIC is also a method by which the weighting coefficients of criteria can be determined objectively based on mathematical calculations. It appears in works of domestic and foreign authors (Diakoulaki et al, 1995; Zhong et al, 2023; Krishnan, 2024; Kim et al, 2024). Unlike the previous method, when normalizing the matrix, it is necessary to pay attention to benefit and cost criteria (Mallick et al, 2023; Yalçın et al, 2025). For benefit criteria, it is calculated by subtracting the minimum value of the column for that criterion from the matrix cell and dividing it by the difference between the maximum and minimum values (Basuri et al, 2025). While for cost criteria, the value of the cell of the initial matrix is subtracted from the maximum value per column and the value is divided by the difference between the maximum and minimum values per column - criterion. Then, the standard deviation of the coefficients per column is calculated. The next step is to form a matrix of linear correlation coefficients, where each coefficient is compared with each other, where the value 1 is obtained along the diagonals of the matrix, and below and above the diagonal are the same values and they can be negative. The next matrix is formed by subtracting the value of the cell of the previous matrix from the number 1, thus avoiding negative cell values. Then the column values are summed and the sum is multiplied by the linear correlation coefficient. Finally, the criterion weighting coefficient value is obtained when the previous sum value is divided by the column sum for all coefficients.

The FanMa method is an objective method for determining the weight coefficients of criteria based on mathematical calculations. Although the calculations are simpler, it is less commonly used than the previous two methods (Krstic et al, 2015; Petrovic et al, 2024). As with the previously described method, matrix normalization is performed, for benefit criteria it is calculated by subtracting the minimum column value for that criterion from the matrix cell and dividing it by the difference between the maximum and minimum column values, and for cost criteria the value of the initial matrix cell is subtracted from the maximum value per column and the value is divided by the difference between the maximum and minimum values per column – criterion. Then the weighting coefficient is calculated by the formula:

$$w_j^* = \frac{1}{\left[\sum_{i=1}^{n}(x_j^* - x_{ij})^2\right]\left[\sum_{j=1}^{m}\frac{1}{\sum_{i=1}^{n}(x_j^* - x_{ij})^2}\right]} \tag{10}$$

where x^*_j is the maximum criteria value per column and the sum is always 1, x_{ij} represents the coefficient values for each alternative, and j is the number of criteria.

Description of the criteria and the alternatives

The seven numerical criteria (three of which are cost and four are benefit, based on which the alternatives will be ranked) are as follows:

- C1 - length of the rifle barrel in **mm;**
- C2 - length of the rifle in the combat position in **mm;**
- C3 - initial velocity of the bullet expressed in **m/s;**
- C4 - price in **eur**;
- C5 - rifle power depending on the hopup chamber in **J**;
- C6 - frame capacity in pieces of bullets (**pcs**), and
- К7 - mass in **kg**.

The five alternatives that were selected according to the available criteria proposed by experts are given in Figure 2.

The use of classic weapon maneuver ammunition in urban combat does not have the target impact effect, and, since the sound created by firing a maneuver bullet requires the use of earmuffs, they jeopardize the ability to maintain communication and, consequently, command. The reality of the situation refers to the elimination of soldiers from combat, which would be done in a real situation by a live ammunition hit. On the other hand, when an airsoft rifle projectile with criteria aggregated and ranked by experts (3- initial bullet velocity; 2- barrel length that provides the previous one; 6- frame capacity that does not require constant replacement during use) hits another soldier, the pain will force him to admit that he has been hit and force him to abandon the fight, i.e. he will be thrown out of the fight.

Figure 2: Five airsoft guns as alternatives

Prices of alternatives vary from seller to seller. In this paper, prices are taken from the same domestic website in Serbia and converted into euros, to avoid discrepancies between the price of the replica and the data.

Table 2 – Criteria values for alternatives

Alternatives/ C		C1	C2	C3	C4	C5	C6	C7
A1	BT5 A5	229	735	100	221	1	200	1.9
A2	SLV36	247	500	100	213	1	470	2.85
A3	M15A4	372	850	95	195	0.9	300	2.15
A4	SA M7 W	445	870	95	255	0.9	600	2.98
A5	Cyma 077	455	940	120	340	1.7	600	3.42

Other criteria are also publicly available from manufacturers and sellers themselves and everything except the power of the replica can be checked by the user after purchase. Of course, they are dependent on each other, so the power of the replica affects the range of the bullet. All automatic rifles use the same 6 mm diameter bullet, weighing 2 g, the so-called twenty, which can be of different colors and is mostly white, so this information is not taken as a criterion.

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Ranking results

The criteria available for airsoft weapons were ranked by the experts from the Military Academy, professors who teach cadets specified types of weapons, and operators who have maintained rifles for a longer period. They develop tactical and technical requirements and make proposals to the Military Academy on weapon purchase; this work will be one of the guidelines for the procurement of the next range of rifles. In order to verify the results of the experts, objective methods were also used, and two of the three give identical results as the ranking by the experts.

First, five experts in the field of Military Sciences from the Military Academy ranked the seven criteria as given in Table 3.

Table 3 – Ranking of the alternatives according to the time criterion

Rang	E1	E2	E3	E4	E5
1	C5	C1	C5	C4	C5
2	C1	C4	C1	C1	C4
3	C7	C7	C6	C7	C1
4	C4	C5	C7	C5	C7
5	C6	C2	C4	C6	C6
6	C3	C3	C3	C2	C3
7	C2	C6	C2	C3	C2

To determine the scale for the AHP method using the Borda method, the expert ratings were entered into a table, summed by type, and all cells divided by 9, as this was the lowest weight, as shown in the table. A problem for the above implementation may arise if two criterion weights are equally important. In that case, use another method of determining criterion weights.

Table 4 – Determining the weight coefficient by the Borda method

C / E	E1	E2	E3	E4	E5	WB	RANG	WB/5
C1	1	0	1	1	2	5	7	1
C2	6	4	6	5	6	27	1	5.4
C3	5	5	5	6	5	26	2	5.2
C4	3	1	4	0	1	9	5	1.8
C5	0	3	0	3	0	6	6	1.2
C6	4	6	2	4	4	20	3	4
C7	2	2	3	2	3	12	4	2.4

In the event that all experts have selected one criterion as the most important or that two criteria are of the same rank, the proposed method is unusable and then it is preferable to use the classical AHP method with the Saaty scale or some of the other subjective methods for selecting criterion coefficients such as BVM, LBVA, FUCOM and DIBR I and II which have fewer steps compared to the AHP.

These results were used for the scale used in the AHP method in accordance with 1 and 2 and the following criteria comparison table was obtained.

Table 5 – Initial matrix of the criteria rankings

C	C1	C2	C3	C4	C5	C6	C7
C1	1	0.2273	0.2381	1.25	5	0.3333	0.7143
C2	4.4	1	0.2	3.6	4.2	1.4	3
C3	4.2	5	1	3.4	4	1.2	2.8
C4	0.8	0.2778	0.2941	1	0.6	0.4545	1.6667
C5	0.2	0.2381	0.2500	1.6667	1	0.3571	0.8333
C6	3	0.7143	0.8333	0.6	2.8	1	1.6
C7	1.4	0.3333	0.3571	0.6	1.2	0.625	1

Based on the normalization of the previous matrix and further summarization by types, the weighting coefficients of the criteria in Table 4 were obtained.

Table 6 – Ranking of the alternatives according to the criterion weight

w1	w2	w3	w4	w5	w6	w7
0.0948	0.2178	0.3136	0.0749	0.0645	0.1538	0.0806

Now it is necessary to check the consistency of the matrix and the consistency ratio CR (3, 4, 5). It can be concluded that CR=0.095, which is less than 0.1, meaning the matrix is consistent, and the coefficients are then ranked using the same procedure.

When the weighting coefficients of the criteria from Table 6 and the data from Table 2 are entered into the SAW method, by applying formulas 6, 7 and 8, the following rank is obtained.

Table 7 – Final ranking of the alternatives with the SAW method

A1	0.4070	5.
A2	0.4350	2.
A3	0.4112	4.
A4	0.4266	3.
A5	0.4401	1.

Therefore, the best ranked alternative is A5. In order to check the procedure and for small deviations in the weights on the basis of which the alternatives are ranked, it is necessary to perform a sensitivity analysis or some other method. Here, the alternatives will be ranked using the same method when the criteria are determined on the basis of subjective methods.

The best ranked alternative is the most expensive, if the price is considered. Since the material base is always the desired minimized criterion (Karel & Plašil, 2024), if this criterion were reduced and its reduction distributed to the other criteria, there would be no change in the rankings. Considering the qualities and advantages of the other criteria that are important for close urban combat, despite the highest price, this alternative was selected as the most favorable.

Comparative analysis

The weighting coefficients of the criteria were determined by simple counting - using the Borda group decision-making method that uses an ordinal scale. Since the experts were not required to do so, and therefore the relationship between the two criteria was not taken into account, the question arises whether the method is valid and verification is necessary. In order to verify the reliability of the procedure for determining the weighting coefficients of the criteria using the Borda and AHP methods, an analysis was performed based on a comparison of the ranks of alternatives when objective methods for determining the weights of the criteria were applied.

When the data from Table 2 are included in the three objective methods (Entropy, CRITIC and FanMa) for calculating the criterion coefficients, they amount to

Table 7 – Rank and size of the criteria with the objective methods

Method / C	C1	C2	C3	C4	C5	C6	C7
Entropy	0.1799 2	0.0983 5	0.0185 7	0.0968 6	0.1590 3	0.3434 1	0.1040 4
CRITIC	0.1559 2	0.1371 5	0.1251 7	0.1529 3	0.1279 6	0.1408 4	0.1602 1
FanMa	0.1505 4	0.2325 1	0.0910 6	0.1072 5	0.0845 7	0.1790 2	0.1553 3

If the ranking of criteria and their weighting coefficients for both the hybrid Borda-AHP method and the objective methods are presented graphically, it looks like this:

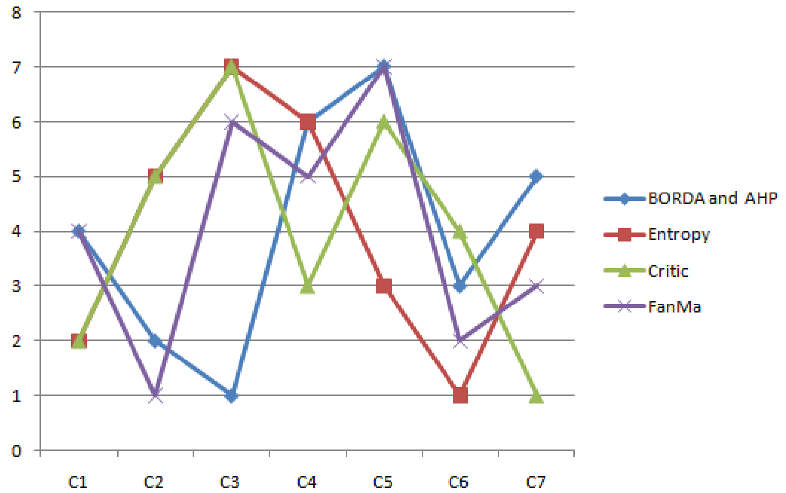

Figure 3: Graphical ranking of the criteria

The graph shows that the importance of the criteria varies from method to method. The C3 criterion, which represents the initial velocity of the projectile and is directly related to the C5, is the most important for experts, while subjective methods see it as the least important. The situation is similar with the C6, which represents the capacity of the frame, so the experts put it in third place because it can be replaced with a frame of a different capacity, while mathematical objective methods do not see this and Entropy puts it in first place. The C7 is also interesting, changing places from first to fifth depending on the method of determination. Then experts placed it in the fifth place, although it is important how much weight soldiers will carry with them, and yet airsoft rifles are lighter than real combat weapons.

If the coefficients obtained by the objective methods are entered into the SAW method, the following ranks with their weights are obtained.

Table 8 – Rank and weights of the alternative choices when the coefficient weights are calculated using different methods

A/Method	Borda/AHP		Entropy		CRITIC		FanMa	
A1	0.4070	5	0.33602	5	0.45501	5	0.4790	5
A2	0.4350	2	0.37974	3	0.47196	3	0.5065	1
A3	0.4112	4	0.36069	4	0.46689	4	0.4896	4
A4	0.4266	3	0.40394	2	0.47467	2	0.5045	3
A5	0.4401	1	0.41707	1	0.48193	1	0.5054	2

Table 8 shows that the last ranked alternative A1 and the second to the last ranked alternative A3 are the same in all four cases. The alternative A5 is in the first place three times, while when the weighting coefficients of the criteria are selected using the FanMa method, it is in the second place. It is also observed in the FanMa method that the difference in weight between the first alternative and the second one is small, only 0.009. The A2 can be said to be a critical alternative for some reason because it changes ranks from method to method, from the first to the third, so it is necessary to deal with it more in a deeper sensitivity analysis, e.g. by reducing the most significant criterion or the least significant one at the expense of the others, which is a suggestion for future research. It is probably because of these deviations that it is used less in works. This is shown graphically in Figure 4.

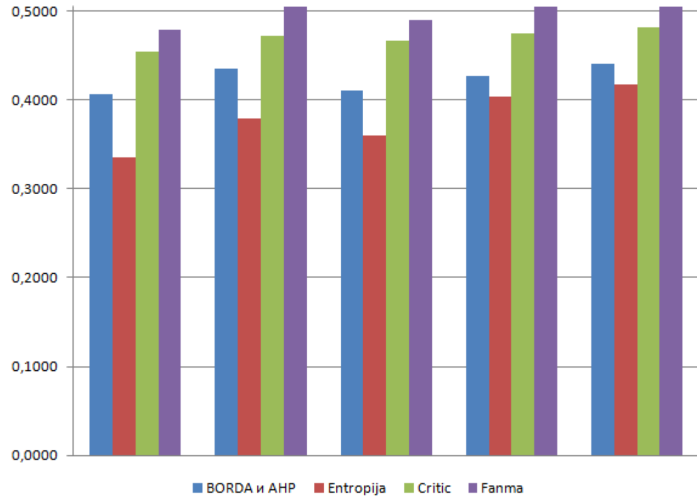

Figure 4: Graphical representation of the rank of the alternatives when coefficient weights are determined by different methods

Spearman's rank correlation coefficient is very useful for analyzing the obtained ranks (Wardany & Zahedi, 2024). If Spearman's rank correlation coefficient is used, it is calculated using the formula:

$$S = 1 - \frac{6\sum_{i=1}^{n} D_i^2}{n(n^2-1)} \quad (11).$$

where D is the difference in ranks and n is the number of sample members.

If the starting point is the ranks obtained by the SAV method, it looks like this:

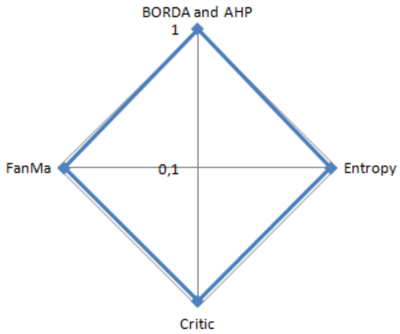

Figure 5: Spearman's rank correlation coefficient of the alternatives

Spearman's coefficient shows (1; 0.9; 0.9; 0.9) a very high correlation between the ranks of the alternatives, although the A2 shows a deviation of two ranks. Since in three out of four cases the A5 is the first-ranked alternative, it is also the best solution for purchasing an airsoft rifle for urban combat and practicing close-range combat actions.

Conclusion

Based on previous research in the field of multi-criteria decision making in the field of military sciences, one of hybrid decision-making models is presented and a new methodology for calculating the weighting coefficients of criteria is proposed. Based on the experts' proposals, the criteria were selected, and based on them, alternatives were found. By applying the hybrid model of three multi-criteria decision-making methods, the weighting coefficients of the criteria were first determined using the Borda-AHP model, then five alternatives were ranked using the SAW method, and the most favorable one was selected. Based on the analysis of the factual situation, airsoft rifles are already in use in military units for these purposes. The proposed model is in accordance with the opinion of the five experts who teach Tactics with Weapon Systems at the Military Academy. The proposed method for ranking and selecting airsoft weapons will serve experts in purchasing a new quantity of rifles for the needs of the Military Academy. It can also be used by other structures for the acquisition of other types of equipment, subject to restrictions. The rifle selected in this way with the above criteria is best for close distances in urban combat as well as for combat in underground installations, which are topics studied at the third and fourth year of the Infantry Module. The rifle can also be used for various demonstrations of close urban combat implemented by special army units and the Military Academy. The rifle selected in this way with the most significant weighting coefficient and initial bullet velocity has the appropriate accuracy of hitting the target at longer distances and over 50 m; it is more effective compared to other rifles and can be used at longer distances.

The presented method of selecting weighting coefficients, which is an innovation in multi-criteria decision making, has yielded results in this case. A problem may arise if two criteria in the Borda method have the same rank, and it is necessary to further improve it and adapt it to the specific situation. A comparative analysis has shown that the proposed model for determining the weighting coefficients of criteria is valid and one of the ways of determining the weights of criteria is given when experts are not familiar with the methods of multi-criteria decision making, which is also a contribution to the methodology of multi-criteria decision making. Also, the weights of criteria that vary depending on the method of determination did not greatly affect the rank of alternatives. The presented model can be further improved by examining and checking the ranking through other methods for ranking criteria and alternatives. It can also be checked and compared using the Saaty scale. A more detailed sensitivity analysis can be performed by gradually reducing the number of criteria or eliminating a criterion. The presented method of determining the weights of criteria based on a simple ranking of them by experts, which was applied for the first time, showed satisfactory results in sensitivity analysis. It is necessary to further develop and upgrade it and examine its application in combination with other methods. Based on the research, it can be concluded that the existing method of defining the weighting coefficients of criteria is very simple to calculate, especially with a large number of criteria and does not require knowledge of multi-criteria decision-making methods by experts. It can also be undoubtedly concluded that the aforementioned methodology can be used in other situations when choosing new weapons and military equipment.

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Selección de un rifle airsoft para combate urbano utilizando el modelo híbrido de toma de decisiones multicriterio Borda-AHP-SAW y Entropy-CRITIC-FanMa-SAW

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CAMPO: matemáticas aplicadas, ingeniería mecánica, ciencias militares (tácticas con sistemas de armas)
TIPO DE ARTÍCULO: artículo científico original

Resumen:

Introducción/objetivo: El artículo presenta la aplicación de métodos de toma de decisiones multicriterio para seleccionar una réplica airsoft de un rifle automático para la práctica de acciones tácticas en combate urbano. Primero, expertos clasificaron los criterios según los cuales se seleccionarían las alternativas. Mediante los métodos Borda y AHP, se determinaron los coeficientes de ponderación de los criterios, y posteriormente se seleccionó la alternativa más favorable mediante el método SAW. El procedimiento de selección se repitió cuando la selección se realizó sin expertos, pero los coeficientes de ponderación de los criterios se determinaron mediante los métodos de Entropía Objetiva, CRITIC y FanMa, y se realizó un análisis comparativo de los resultados. El objetivo del artículo es seleccionar el rifle airsoft más efectivo para uso profesional y civil para la práctica de acciones tácticas en combate urbano mediante la combinación de métodos de toma de decisiones multicriterio. El consumo mínimo de recursos es siempre el punto de partida, garantizando al mismo tiempo la forma más eficiente de practicar acciones tácticas lo más cercanas posible a las condiciones reales.

Métodos: Por primera vez, se presentó el método para determinar los coeficientes de ponderación de criterios mediante métodos multidisciplinarios de toma de decisiones multicriterio sobre un problema específico en el campo de las tácticas con sistemas de armas, con la opinión de expertos. Posteriormente, se compararon los resultados sin la participación de expertos. Los expertos en Tácticas y Armas de la Academia Militar seleccionaron y clasificaron siete criterios. Posteriormente, sus opiniones se refinaron mediante el método Borda y los resultados se incorporaron al método AHP para seleccionar los coeficientes de ponderación de los criterios. Finalmente, se seleccionó la alternativa más favorable con base en el método SAW. Dado que el procedimiento descrito para determinar los coeficientes de ponderación de los criterios se calculó por primera vez con la participación de expertos, se repitió el procedimiento para seleccionar la alternativa más favorable sin la participación de expertos, pero se determinaron los pesos de los criterios mediante métodos objetivos y se compararon los resultados mediante análisis comparativo. Las alternativas son cinco rifles de airsoft con recámara hop-up, algunos de los cuales se utilizan en la Academia Militar y en unidades especiales del ejército para entrenamiento en diversas acciones tácticas de combate, mientras que en la vida civil son utilizados por entusiastas de las armas airsoft.

Resultados: Se eligió el rifle airsoft más asequible para ofrecer un consumo mínimo de recursos con el máximo rendimiento y aportar el mayor realismo posible a las situaciones de combate al practicar acciones tácticas en el entorno urbano.

Conclusión: La solución, con un análisis comparativo de los resultados obtenidos de dos maneras, considera la optimización simultánea de siete criterios ligeramente diferentes para seleccionar el rifle airsoft más eficaz para la práctica de procedimientos tácticos, con el fin de proporcionar condiciones lo más cercanas posible a las situaciones reales de combate a corta distancia.

Palabras claves: rifle airsoft, selección, Borda, AHP, SAW, entropía, CRITIC, método FanMa.

Выбор страйкбольной винтовки для боев в городских условиях с использованием гибридной многокритериальной модели принятия решений BORDA-AHP-SAW и ENTROPY-CRITIC-FANMA-SAW

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РУБРИКА ГРНТИ: 27.47.19 Исследование операций,
28.17.31 Моделирование процессов управления
ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Введение/цель: В данной статье представлено применение методов многокритериального принятия решений при выборе страйкбольной копии автоматической винтовки для отработки тактических приемов в городских условиях. Сначала экспертами было произведено ранжирование критериев, на основании которых в дальнейшем будет сделан выбор подходящего варианта. Применяя методы BORDA и AHP, были определены весовые коэффициенты критериев, а затем с помощью метода SAW был выбран лучший вариант. Процедура отбора была повторена, когда отбор проводился без участия экспертов. В этом случае весовые коэффициенты критериев были определены с помощью объективных методов Entropy-CRITIC-FanMa, а затем проведен сравнительный анализ результатов. Цель статьи заключается в выборе наиболее эффективной страйкбольной винтовки для служебного и гражданского использования в отработке тактических приемов в городских условиях путем сочетания методов принятия многокритериальных решений. В современном мире отправной точкой является минимальное потребление ресурсов, но при этом обязательно должна быть обеспечена наиболее эффективная отработка тактических приемов в условиях, приближенных к реальным.

Методы: Сначала был применен экспертный метод определения весовых коэффициентов критериев с использованием междисциплинарных методов многокритериального принятия решений по конкретной проблеме в области военной тактики. В случае, когда эксперты не привлекались, был проведен сравнительный анализ результатов. Эксперты в области тактики и вооружения из Военной академии сначала выбрали и ранжировали семь критериев. Затем их мнения были подтверждены с помощью метода BORDA, после чего результаты были введены в метод AHP для выбора весовых коэффициентов критериев. В конце на основании метода SAW был выбран лучший вариант. Поскольку описанная выше процедура определения весовых коэффициентов критериев впервые была рассчитана экспертами таким образом, процедура выбора лучшего варианта была повторена без привлечения экспертов, но веса критериев были определены с использованием объективных методов, а результаты сопоставлены с помощью сравнительного анализа. Альтернативными вариантами были пять страйкбольных винтовок с патронником hop-up, некоторые из которых используются в Военной академии и в специальных военных подразделениях при обучении военно-тактической подготовке и просто любителями страйкбольного оружия.

Результаты Выбор подходящей страйкбольной винтовки был сделан с учетом минимального расхода ресурсов и максимальной эффективности отработки тактических приемов в условиях, приближенных к реальным.

Вывод: Решение, основанное на сравнительном анализе результатов, полученных двумя способами, учитывает одновременную оптимизацию семи критериев, которые незначительно отличаются друг от друга, с целью выбора наиболее эффективной страйкбольной винтовки для отработки тактических приемов на ближних дистанциях в условиях, приближенных к реальным.

Ключевые слова: страйкбольная винтовка, выбор, методы BORDA, AHP, SAW, Entropy, CRITIC, FanMa.

Избор airsoft пушке за урбану борбу применом хибридног модела вишекритеријумског одлучивања BORDA-AHP-SAW и Entropy-Critic-FanMa-SAW

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ОБЛАСТ: примењена математика, машинство, војне науке
(тактика са системима наоружања)
КАТЕГОРИЈА (ТИП) ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/циљ: У раду је представљен начин примене метода вишекритеријумског одлучивања ради одабира airsoft реплике аутоматске пушке за увежбавање тактичких поступака у борби у урбаној средини. Најпре су експерти извршили рангирање критеријума по којима ће се вршити избор алтернативе. Применом метода BORDA и AHP одређени су тежишни коефицијенти критеријума, а затим је најповољнија алтернатива одабрана применом метода SAW. Поступак одабира у којем експерти не учествују је поновљен , па су тежишни коефицијенти критеријума одређени објективним методама Entropy-CRITIC-FanMa *и извршена је компаративна анализа резултата. Циљ рада јесте да се комбинацијом метода вишекритеријумског одлучивања одабере најефикаснија airsoft пушка за професионалну и цивилну употребу за увежбавање тактичких радњи и поступака у борби у урбаној средини. Минималан утрошак ресурса увек је полазна основа, уз обезбеђење што ефикаснијег начина увежбавања тактичких радњи које су приближне стварним условима.*

Методе: По први пут је приказан експертски начин одређивања тежишних коефицијената критеријума употребом мултидисциплинарних метода вишекритеријумског одлучивања на конкретном проблему из области тактике са системима наоружања, а затим су, у одсуству експерата, резултати упоређени.Експерти из области тактике и наоружања са Војне академије најпре су одабрали и рангирали седам критеријума, а затим су њихова мишљења сублимирана уз помоћ метода BORDA, и резултати унесени у метод AHP ради избора тежишних коефицијената критеријума. На крају је, на основу метода SAW , извршен избор најповољније алтернативе. Пошто је наведени поступак одређивања тежишних коефицијената критеријума по први пут прорачунат ангажовањем експерата на овај начин, поступак одабира најповољније алтернативе је поновљен без ангажовања експерата, а тежине критеријума одређене су објективним методама, па су резултати упоређени компаративном анализом. Алтернативу представља пет airsoft пушака са hopup комором, од којих се неке користе на Војној академији и у специјалним јединицама Војске за увежбавање различитих борбено-тактичких радњи, а користе их и цивили, љубитељи airsoft наоружања.

Резултат: Избор најповољније airsoft пушке, која ће обезбедити минималан утрошак ресурса и најповољније перформансе у условома најприближнијим борбеној ситуацији при увежбавању тактичких радњи у урбаној средини.

Закључак: Решење уз компаративну анализу резултата добијених на два начина узима у обзир истовремену оптимизацију седам критеријума, који се незнатно разликују, ради одабира најефикасније airsft пушке за увежбавање тактичких поступака ради обезбеђења услова најприближнијих реалној борбеној ситуацији на кратким дистанцама.

Кључне речи: airsoft пушка, одабир, BORDA, AHP, SAW, Entropy, CRITIC, метод FanMa.

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