doi: 10.5937/str2101030R
UDK: 799.311.4,005,623.443.37
COSATI: 12-01; 12-03

Analysis of Accuracy and Precision of Shooting with Home - Made Automatic Rifles Using the AHP Method

Marko Radovanović [1)]
Aleksandar Milić[2]
Aleksandar Petrovski[3]

The paper presents the selection of the most accurate and precise automatic rifle, as a significant weapon primarily for the realization of combat tasks of the army. The size of the image of the scattering of shots and its distance from the target determine the degree of accuracy and precision of the automatic rifle. These indicators determine the probability of hitting, which affects the efficiency of solving fire tasks with an automatic rifle. The complexity of the problem is due to the different tactical and technical characteristics of automatic rifles and different shooting results. The paper presents and describes the results of shooting automatic rifles of domestic production, as follows: AR 7.62 mm M70 AB2, AR M21 5.56 mm, MAR M17 6.5 mm. Using the AHP method, the calculation of the weight coefficients of the criteria was performed. Using the AHP method, an analysis of the accuracy and precision of automatic rifle shooting was performed and a conclusion was made about the rifle that has the best results depending on the shooting distance. The obtained results enable the definition of proposals for equipping the Serbian Armed Forces units with an adequate automatic rifle.

Key words: **automatic rifle, multicriteria decision making, AHP method, accuracy, precision, armament.**

Introduction

THERE is a significant number of factors that monitor and condition the development of weapons and military equipment. The manner of conducting modern combat operations places certain demands on arms manufacturers, in order to maximize the effects on the target. When it comes to small arms, in addition to submachine guns, machine guns and machine guns, automatic rifles also play a significant role in the world's armies. Automatic rifles are the most massive type of weapon and the basic weapon of infantry, they are individual small automatic weapons intended for shooting at distances from 200 to 1000 m. Practical shooting speed is up to 120 bullets per minute [1]. The demands of the army and the police are for the greatest possible accuracy and precision of shooting automatic rifles.

Accordingly, the goal was set to select the most accurate and precise automatic rifle. The results of the research can be used during the further procurement of automatic rifles of domestic production for the needs of the Serbian Army. The accuracy and precision of shooting directly affect the efficiency of the weapon, higher accuracy and precision increase the efficiency of the weapon, which directly affects the increase in the efficiency of the execution of the fire task. According to the literature available to the authors, the choice of an automatic rifle was considered by applying different methods of multicriteria decision making. Ashari and Parsaei [2] select infantry rifles using the ELECTRA III method. Radovanović and Stevanović [3] using the AHP method with the help of the Expert choice 2000 program realize the selection of the best automatic rifle of domestic production. Jokic et al. [8] using the LBWA and fuzzy MABAC methods, they select the firing position of mortar units. Also, Pamučar et al. [9] select the optimal location for water barriers using the Interval-Valued Fuzzy-Rough Numbers and MAIRCA methods. Stoilova [10] using the AHP and SIMUS optimal railway route in case of an emergency. Božanić et al. [11] represent the LBWA - Z-MAIRCA model that provides support to decision makers in the military. The application of the AHP method in combination with FUCOM was used by Badi and Abdulshahed to rank Libyan airlines. [12] Komazec and Petrovic [13] used the hybrid model AHP - VIKOR for the selection of media for informing the endangered in emergency situations. Sennaroglu and Celebi [14] select the location of the military airport using the integrated methods of AHP, PROMETHEE and VIKOR. Tešić and Božanić [15] using the MAIRCA method select the location for the passage of tanks under water.

The complexity of choosing the most accurate and precise automatic rifle has conditioned the application of the method of multi-criteria decision-making. The AHP method was used to determine the weight coefficients of the criteria, and based on the shooting results, the most accurate and most accurate automatic rifle was selected by the AHP method.

Problem description

During the shooting with an automatic rifle (and especially during the realization of fire tasks), during direct shooting, the scattering of hits occurs. The grouped shots obtained by direct

[1)] 1st Army Brigade, Serbian Armed Forces, Dunavska 33, 21000 Novi Sad, SERBIA
[2)] University of Defence, Military Academy, Veljka Lukića Kurjaka 33, 11000 Belgrade, SERBIA
[3)] University "GoceDelchev" - Stip, Military Academy "General Mihailo Apostolski", Skopje, REPUBLIC OF NORTH MACEDONIA
Correspondence to: Marko Radovanović, e-mail: markoradovanovicgdb@yahoo.com

shooting with an automatic rifle form an image of the shots in a vertical plane that is in the shape of an ellipse [16]. For the characteristics of the law of scattering of hits in the vertical plane, a single ellipse of scattering with semi-axes is taken: probable deflection in height - Vv and probable deflection in the direction - Vp (Fig.1).

The aforementioned semi-axes of a single scattering ellipse represent the mean probable shooting error, both in height and direction. By reducing the mean probable error, the mean hit is closer to the center of the target, and the ellipse of scattering hits is smaller, which leads to greater accuracy and precision of the automatic rifle. Obtaining such an image of hits is conditioned by the adjustment (rectification) of the sights, which is realized after testing the accuracy and precision of the automatic rifle.

The accuracy and precision of shooting is one of the factors in the efficiency of a weapon, where the efficiency of shooting is higher the higher the number of hits with the lowest possible consumption of ammunition and the shorter the execution time of the fire task. In most cases, the efficiency is shown as a percentage, compared to the ideal case in which the efficiency is 100%.

The scattering of hits represents the deviation of the hits from the center of the target of each projectile in the group of projectiles fired under approximately the same conditions. It is a shooting phenomenon, which materializes at the target, and in which each projectile describes its trajectory in relation to other projectiles fired under equal conditions [17].

The accuracy of the shot is the measured value between the scattering of the hits of the beam of the trajectory and the target that is being shot. It is defined by the distance of the image of scattering hits and the image of the target at a certain distance. The conclusion about accuracy is made based on the size of the deviation of the mean hit (Mh) from the center of the target. Shooting is more accurate the smaller the deviation of the middle goal from the center of the target [18]. It depends on the work of the shooter, the meteorological conditions in which the shooting takes place, the completeness and correctness of the instruments and ammunition.

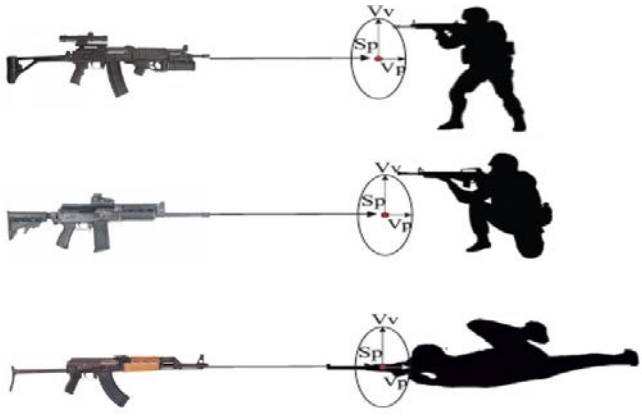

Figure 1. Image of scattering of hits depending on the dimensions and position of the target

Shooting accuracy is a measure of scattering of hits limited by four probable deflections (Vs) in each direction from the mean hit. When the trajectory is smaller, the weapon is more precise. The accuracy of shooting is prescribed in accordance with the defined limits of deviation of hits, and according to the desired size of the image of hits [17,18]. The accuracy and precision of an automatic rifle (AR) is tested by firing a projectile, under the same conditions, to obtain one of four possible variants of shot images. Depending on the realized image of the hits, the automatic rifle can be defined as: accurate and precise, accurate and inaccurate, inaccurate and precise and inaccurate and inaccurate (Fig.2).

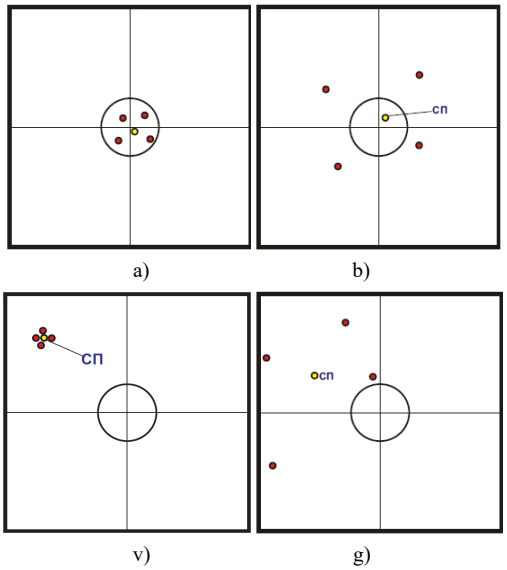

Figure 2. Variants of the image of the hits: a) accurate and precise; b) accurate but imprecise; c) inaccurate and precise and d) inaccurate and inaccurate.

By analyzing the presented variants of images of hits and the experience gained so far, it can be concluded that precision has a significant impact on the execution of the fire task [19]. If the automatic rifle is accurate, shooting is easier, more successful, and allows more fire tasks to be performed.

Criteria such as: hit image range (H and L), mean radial deflection (Rs), better half radius of hits (R50), probable deflection (Vs) and core band (J) can be used to assess accuracy and precision. When testing the accuracy and precision of small arms, the scattering of hits is measured by height (Vv) and direction (Vp). The range of the hit image is the distance between the centers of the most distant hits from each other [20].

When shooting from small arms, the image of the hits is called an ellipse. There is a simple and complex picture of hits depending on the number of hits obtained by shooting from several similar weapons [21]. The scattering ellipse obeys the Normal Law of Errors (NLE) or Gaussian law. Fig.3 shows the characteristics of NLE, i.e. the scattering of hits by height (Vv) and by direction (Vp) in percent.

Mean radial deflection (Rs) is defined as the arithmetic mean of the radial deviations of individual hits from the mean hit (sum of radial deviations of hits from the mean hit divided by the number of hits) [20].

The mean goal is the point obtained by the intersection of the ordinate and the abscissa of the mean deviation of all hits in the group. The ordinate of the mean hit is the arithmetic mean of the deviation of all hits in height. The mean hit abscissa is the arithmetic mean of the deviation of all hits in the direction [22].

The radius of the circle of the better half of the hits (R50) is used as a measure of precision in cases when the scattering surface is an ellipse, and shooting is performed in groups of more than 10 projectiles [20]. The radius is determined as follows: determine the mean hit for the center of the scattering surface, draw a circle that encompasses that half of the hit closest to the mean hit.

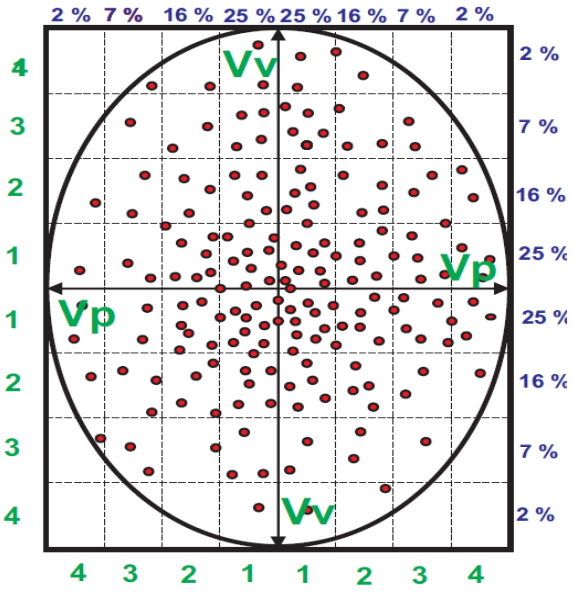

Figure 3. Scattering of hits by height and direction

Table 1. Measures of accuracy and precision

Symbols and names of scales	Vs	J	R50	Rs
Probable turn (Vs)	Vs	0,3317J	0,5682R50	0,5338Rs
Core belt (J)	3,0144Vs	J	1,7130R50	0,5338Rs
Round radius of the better half of the hits (R50)	1,7627Vs	0,5847J	R50	0,9395Rs
Mean radial deflection (Rs)	1,8733Vs	0,6214J	1,0644R50	Rs

Probable deflection is a measure of the scattering of hits whose size is chosen so that in relation to it it is equally likely that half of the hits have less, and the other half of the hits a larger deflection in absolute value. Probable deflection is one of the most important characteristics that characterizes the accuracy and precision of AR shooting [3].

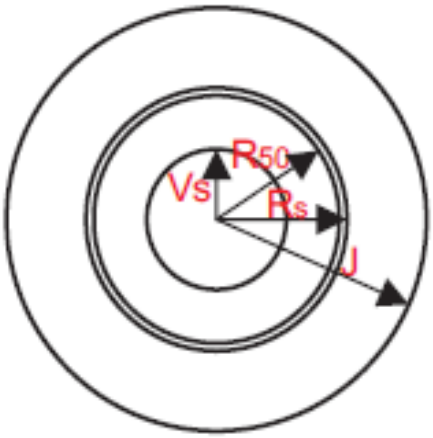

Figure 4. Graphic representation of accuracy and precision meters

A probable turn is such a turn that, in its absolute value, is greater than each turn of one half of all turns, and less than each turn from the other half of the turn of the hits arranged in ascending or descending order. The probable deflection is the bandwidth located immediately along the scattering axis covering 25% of the projectiles fired [23].

In case all the factors that affect the flight of the projectile are the same for each shot, then the shots are always obtained at one point. However, in practice it is different. When firing a group of projectiles at a target (from the same correct weapon), the received shots are not at one point of the target, but the shots are scattered. During the execution of the fire task, during direct shooting from small arms, the scattering of hits occurs. Content analysis leads to the conclusion that the scattering of hits is a phenomenon in direct shooting, and represents the grouping of hits in the plane of the target around the middle hit (midpoint) when firing a large number of projectiles with the same shooting elements and approximately the same shooting conditions [18]. In practice, it is not possible to ensure that all projectiles are fired under the same firing conditions [24] (it is not possible to ensure that each projectile has the same initial velocity, the same firing angle as the influence of the same factors during flight).

Shooting with automatic rifles (AR7.62mm M70AB2, AR M21 5.56 mm and modular automatic rifle M17 6.5 mm) was performed at the "Nikinci" range, at the distance of 500 meters in an electronic target measuring 3 x 3 m (Figure 5). The shooting was done with five bullets from each rifle, and the time for shooting was unlimited. The technical characteristics of the weapons conditioned the choice of the targets with which the shootings were realized. With the M70 7.62 mm automatic rifle, the shooting was performed with a basic mechanical sight, with the 5.56 mm M21 automatic rifle, the shooting was performed with the basic optical sight with a magnification of 4x, while with the modular AR M17 6.5 mm, the reflex sight was fired. The achieved results of the shooting at an electronic target, regardless of the type of sights used, at a distance of 500 m are shown in Table 2 and Fig.7. In Table 2, all measurements are given in millimeters.

Figure 5. B590 Optical Target System

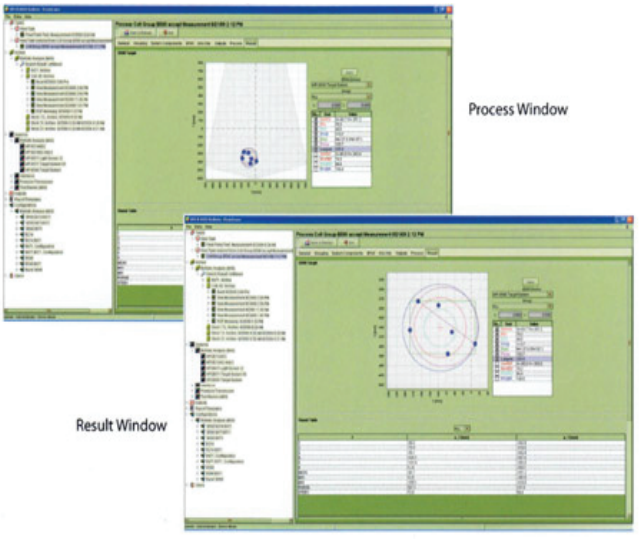

Figure 6. Display of the results of shooting at an electronic target

Based on the shooting results, the analysis of the accuracy and precision of automatic rifle shooting was performed on an electronic target at a distance of 500 m, on the basis of which a conclusion was made on the measure of accuracy and precision of domestic automatic rifles.

Table 2. Results of shooting with automatic rifles at an electronic target

ACCURACY AND PRECISION OF AUTOMATIC RIFLES						
distance to the target	The distance hit from the center target (mm)					
500 m	AR M70 7,62 mm		AR M21 5,56 mm		MAR M17 6,5 mm	
hits	in the direction	in height	in the direction	in height	in the direction	in height
1	830	717	1560.8	-310.7	-113.4	223
2	164.8	205.3	457.3	264.9	62.4	442.7
3	-164.9	57	1215.7	145.3	339.8	87.1
4	265.9	478.5	-389.5	-211.6	-258.6	390
5	257.3	34.2	-945.3	-593.1	162	-35.4
	Mean hit					
	270.6	298.4	379.8	-141	38.4	221.5
	maximum deviation from the goal center					
	830	717	1560.8	593.1	339.8	442.7
	the range of hits					
	994.9	682.8	2506.1	858	598.4	478.1
	the radius of mean hit					
	356.5		955.4		266.2	
	the sum H + L					
	1677.7		2808.5		1076.5	
	the distance of two the farthest hits					
	1193.9		1632.1		670.7	

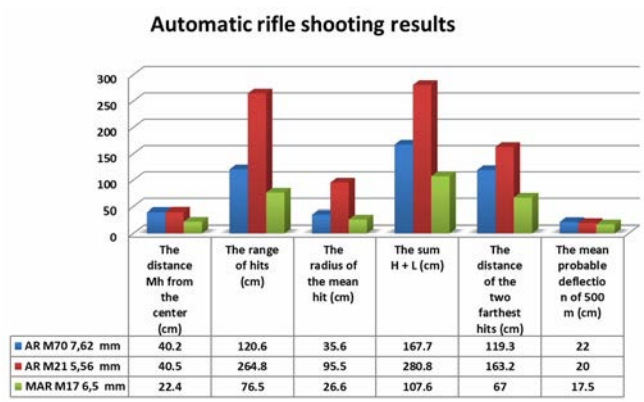

Figure 7. Results of shooting with automatic rifles

Based on the data shown in Fig.7, the following can be concluded: / 1 / MAR M17 is significantly more accurate than M70 and M21 rifles, while the accuracy of M70 and M21 rifles is approximately equal; / 2 / with the criteria range of hits, radius SP, distance of the two farthest hits, the best results were obtained by shooting from MAR M17, then A M70, and the worst results were obtained by shooting from AR M21; / 3 / when it comes to the average probable turn at a distance of 500 m, which is prescribed by shooting tables, the results are approximately equal (at least Vs has MAR M17, then AR M21 and finally AR M70) / 4 / the obtained results have a significant impact caliber and range of shooting.

Description of the methods applied

The Analytical Hierarchical Process (AHP) method was used in the paper to determine the weighting coefficients of the criteria, and then to select the most favorable alternative. The AHP method does not need to be described in more detail because it is one of the most well-known methods of scenario analysis and decision making by consistent evaluation of hierarchies whose elements are goals, criteria, sub-criteria and alternatives.

The method was created by Tomas L. Saaty in 1980 [25] and is a tool that provides assistance to the decision maker (DM) in solving complex decision-making problems in which a large number of DM, a larger number of criteria and in multiple time periods. It belongs to the class of methods for soft optimization.

To date, this method has undergone a large number of modifications [26, 27, 28, 29, 30, 31, 32] but in some cases it is still used in its original form in both individual and group decision-making [33]. It is applied during analysis and decision making in solving complex problems whose elements are goals, criteria, sub-criteria and alternatives. Based on the defined set of criteria and attribute values for each of the offered alternatives, the selection of the most acceptable is realized, i.e. the complete order of importance of alternatives in the model is shown. In order to facilitate the application of the method on a specific example, original software from the class of decision support systems Expert choice [34] was developed, which supports decision-making using the "AHP" method [35]. The AHP method allows the realization of dependence-independence between attributes to be decomposed into different hierarchical levels [36].

Four phases of application of the method [37] were recorded: (1) structuring the problem, (2) collecting data, (3) estimating the relative weights, (4) determining the solution to the problem.

The problem structuring phase consists of decomposing a complex decision problem into a series of hierarchies where each level represents a smaller number of manageable attributes. During the third phase of the method, the relative weight (evaluation) is assigned to the criteria, which enables the comparison of pairs according to the attributes of one hierarchical level for all levels of the entire hierarchy using the generally known scale of Thomas L. Saaty.

Such hierarchical structuring of any decision problem is an efficient way of dealing with the complexity of real problems and identifying significant attributes in order to achieve the overall goal of the problem. Thus, the AHP method possesses and provides exceptional flexibility in assisting in management decision-making processes. It is important to point out that the sum of the weight coefficients of the elements at each level of the hierarchy is equal to 1, which enables the decision maker to rank all the elements in the horizontal and vertical sense. The AHP method enables an interactive analysis of the sensitivity of the evaluation process to the final ranks of the elements of the hierarchy. In addition, during the evaluation of hierarchy elements, until the end of the procedure and synthesis of results, the consistency of decision makers' reasoning is checked and the correctness of the obtained ranks of alternatives and criteria, as well as their weight values, is determined.

Let n be the number of criteria (or alternatives) whose weights wi should be determined on the basis of an estimate of the values of their relations denoted by aij = wi / wj. From the relationship of relative importance aij a matrix of relative importance A is formed:

$$A = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdot & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdot & w_2/w_n \\ \cdot & \cdot & \cdot & \cdot \\ w_n/w_1 & w_n/w_2 & \cdot & w_n/w_n \end{bmatrix}$$

$$= \begin{bmatrix} a_{11} & a_{12} & \cdot & a_{1n} \\ a_{21} & a_{22} & \cdot & a_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ a_{n1} & a_{n2} & \cdot & a_{nn} \end{bmatrix} \quad (1)$$

Matrix A for the case of consistent estimates, for which *aij = aik, akj* holds, satisfies the equation *Aw = nw*.

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdot & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdot & w_2/w_n \\ \cdot & \cdot & \cdot & \cdot \\ w_n/w_1 & w_n/w_2 & \cdot & w_n/w_n \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ \cdot \\ w_n \end{bmatrix} = n \times \begin{bmatrix} w_1 \\ w_2 \\ \cdot \\ w_n \end{bmatrix} \quad (2)$$

Matrix A has special properties, it is positive, reciprocal matrix r (A) = 1 (all its rows are proportional to the first row, all are positive and aij = 1 / aji).

The application of multi-criteria analysis and the mentioned method is significantly represented in the decision-making process in various areas [35, 38]. Various papers [36, 39, 40, 41, 42] and textbooks [43] testify to the support of decision-making in military issues.

Analysis of accuracy and precision of shooting with automatic rifles of domestic production using the ahp method

Using the AHP method, with the help of the software program Expert choice 2000, a comparison of accuracy and precision measures was performed, based on which a conclusion was made about an automatic rifle that achieved the best results when shooting at an electronic target 3 x 3 meters and has the best accuracy and precision at a distance of 500 m.

Six criteria were defined on the basis of which automatic rifles were compared and on the basis of which shooting efficiency was evaluated (distance of mean hit (Mh) from the center of the target, maximum deviation from the center of the target, range of hits, radius of the average shot, sum H + L) the largest deviation in direction and height), the distance of the two farthest hits and the average probable turn at a distance of 500 m). These criteria are defined based on the analysis of the literature in the field of shooting theory and ballistics and the results of research.

The distance Mh from the center (C1) of the target is defined as the accuracy of shooting, which is a measure of the deviation of the beam of the trajectory from the target [22]. Shooting is more accurate the smaller the distance of the middle goal from the center of the target and vice versa. It is expressed in millimeters and is a "cost" type.

The mean probable deflection (C2) is a measure of the scattering of hits whose magnitude is determined so that in relation to it it is equally probable that half of the hits have a smaller and the other half of the hits a larger deflection in absolute value. It is expressed in millimeters and is a "cost" type. The firing tables of each weapon show the magnitudes of the probable deflections as the simplest information on the accuracy of the weapon-ammunition system [17].

The radius of the mean hit (C3) is the arithmetic mean of the radial deviations of the hits from the mean hit (the sum of the radial deviations of the hits from the mean hit divided by the number of hits). The stated criterion is of the "cost" type and is expressed in millimeters.

The range of hits or the range of the hit image (C4) includes the distance between the centers of the most distant hits from each other. The range of the image of the shots in height is marked with H, and in the direction with L. The range of the image of the shots is significantly dependent on the number of fired bullets [20]. Range data can be used to evaluate and analyze precision results only when the number of hits covered by this measure is known. The criterion is of the "cost" type and is also expressed in millimeters.

The distance of the two farthest hits (C5) is the distance between the two hits that have the largest deviation from the middle goal. The farther the shots, the bigger the image of the shots, and the more inaccurate the weapon. The distance between the two farthest hits is inversely proportional to the accuracy of the weapon. Like the previous criterion, this one is of the "cost" type and is expressed in millimeters.

The sum H + L (C6) is the sum of the distances of the most distant hits in direction and height and is directly dependent on the range of the hit image [20]. The lower the sum, the greater the accuracy of the weapon. It is expressed in millimeters and is a "cost" type.

The definition of the weight coefficients of the criteria was performed by expert evaluation using the AHP method and with the support of the Expert Choice software. The weight coefficients of the criteria are shown in Fig.8.

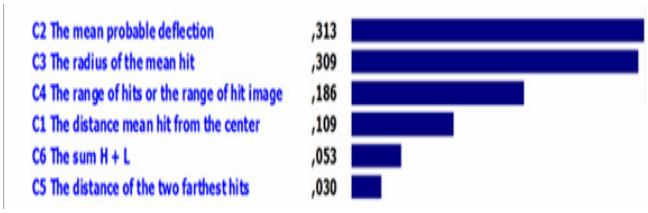

Figure 8. Coefficients of weight of the criteria

The priorities of the alternatives for each criterion were obtained on the basis of the absolute values of the criteria for the alternatives (Fig.8). The result of the synthesis of the problem of evaluating the measures of accuracy and precision based on the research results is given in the form of a multi-criteria ranking list of alternatives (Fig.9).

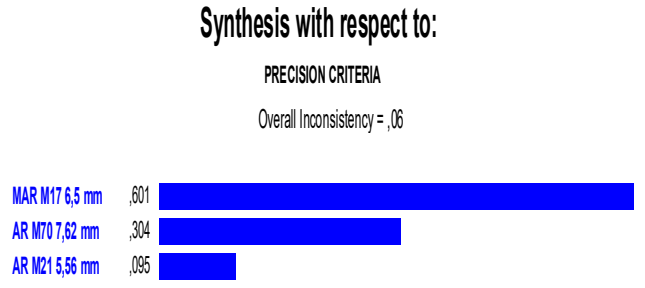

Figure 9. Multi-criteria ranking list of measures of accuracy and precision of automatic rifles at the level of the target function

Sensitivity analysis of accuracy and precision of shooting with automatic rifles of domestic production using the AHP method

Sensitivity Analysis Dynamic provides a dynamic overview of the weighting coefficients of the criteria in percent. During the analysis, certain changes can be made to the values of the criteria and monitor how they affect the consistency of the results. On the left side there are the percentages that certain criteria have in relation to the final decision, while on the right side there are the percentages that individual alternatives achieve in relation to the criteria. Dynamic sensitivity analysis at the level of criteria and at the

level of precision accuracy measures as a function of the target is shown in Fig.10.

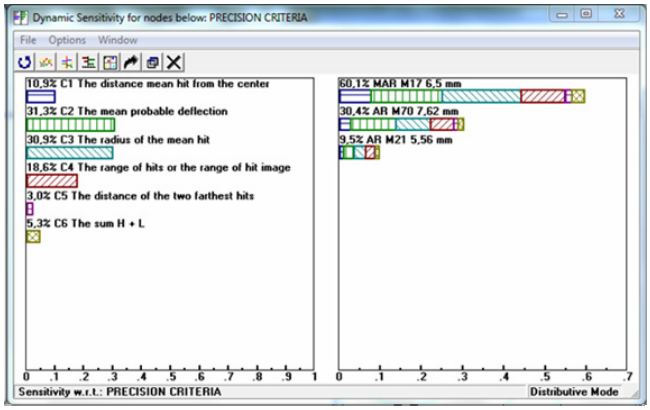

Figure 10. Dynamic sensitivity analysis of the solution obtained by synthesis at the level of the problem depending on the criteria

Preformance sensitivity analysis shows the priorities of the alternatives in relation to the criteria and the presentation of the output results depending on the change of the weight coefficients of the criteria in the hierarchical model. The sensitivity diagram depending on the measures of accuracy and precision (Fig.11) allows monitoring the effects of individual criteria on the current in the overall range of alternatives, thus choosing the most favorable alternative depending on the given criteria.

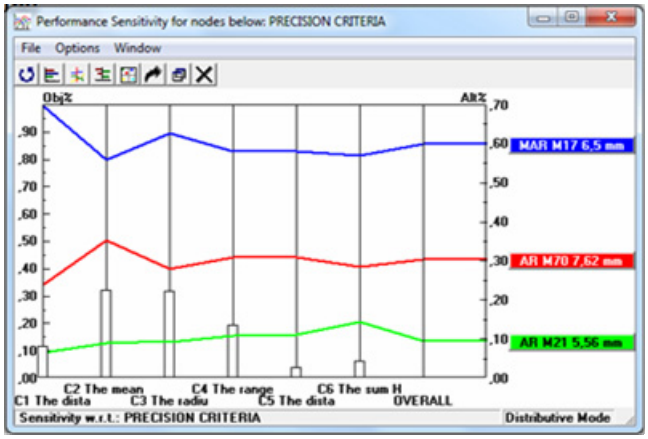

Figure 11. Sensitivity diagram of automatic rifle accuracy and precision gauges

Analyses of the results obtained by the research, as well as the findings obtained, show the following:

- Medium probable turning at a distance of 500 m with 31.3% has the greatest influence on the precision measures of automatic rifles. Next is the impact of the Radius of the average hit with 30.9%, while the range of the hit has an impact with 18.6%. The distance of the middle hit from the center of the hit has an impact with 10.9%, and the Sum of H + L with 5.3% and the distance of the two farthest hits with 3.0% take the last places according to the created impact;
- rifle automatic modular M17 is the first-ranked alternative with a coefficient of 0.601. Second in the rank is AR M70 with a coefficient of 0.304, while the weakest results were recorded by AR M21 with a coefficient of 0.095;
- According to the achieved precision, MAR M17 stands out with 50.6% better accuracy compared to AR M21, and 29.7% compared to AR M70. Also, it should be noted that the AR M70 has 20.9% higher accuracy than the AR M21;
- Based on the sensitivity analysis, it is concluded that the change in the weight of the criteria does not affect the ranking of alternatives and that the ranking of alternatives has sufficient stability;
- The M17 6.5 mm automatic modular rifle achieved significantly better results than the other two rifles. The use of the mentioned automatic rifle increases the accuracy and precision of shooting, which directly affects the increase of the efficiency of solving fire tasks. The introduction into operational use and equipping the units with an automatic modular M17 rifle would significantly increase the efficiency and combat capabilities of infantry units.

Conclusion

The paper uses the AHP method and relies on the Expert choice program to solve the problem of choosing the most accurate and precise model of an automatic rifle. In addition to defining the problem, criteria and alternatives, the procedure for applying the method is described. By expert selection and evaluation of defined criteria, and later by comparing the created models (alternatives), a model was chosen that represents the optimal solution for the given criteria.

It can be concluded that in the specific problem, two criteria stand out in particular (the radius of the mean hit and the mean probable turn at a distance of 500 meters). The software solution proved to be very practical and efficient in finding the optimal solution, ie the analysis of different variants of the problem solving approach. In the context of decision support, by applying the Expert choice program, it was decided that the most accurate and most accurate model of the automatic rifle is MAR M17 6.5 mm.

Based on the conducted experiment and the presented shooting results, it can be concluded that at a distance of 500 m, the smallest image of scattering hits is achieved by an automatic modular M17 rifle in the caliber of 6.5 mm, as well as the highest accuracy of shooting. Also, the highest precision is achieved by using the AP M70 automatic rifle (when the first shot, which represents a gross error, is excluded). Based on the presented results of accuracy and precision, it is possible to determine the probability of hitting, which affects the efficiency of solving fire tasks with an automatic rifle in combat operations.

For the realization of the research, basic sights were used which are equipped with automatic rifles (for AR M70 - mechanical sight, for AR M21 - optical sight, for MAR M17 - reflex sight). The obtained results impose the obligation of further research of the results of shooting automatic rifles with identical sights at distances from 100 to 1000 m, in order to get a completely clear picture of the most efficient automatic rifle, in order to equip units of the Serbian Army.

Acknowledgement

This paper was written as a part of the scientific research project funded by the Military Academy of the University of Defence in Belgrade, number: VA-DH/1/21-23 "Uticaj savremenog okruženja na izvođenje borbenih dejstava u urbanim sredinama" ("Influence of contemporary environment on the conduct of combat activities in urban spaces").

Literature

[1] JAKOVLJEVIĆ,M.: *Fundamentals of Classical Weapons - Automatic Weapons*, CVŠ VJ, Belgrade, 1995.

[2] ASHARI, E. H., PARSAEI, M.: *Application of the multi-criteria decision method ELECTRE III for the Weapon selection*, Decision

Science Letters, Vol. 3, no. 4, 2014, pp. 511-522.

[3] RADOVANOVIĆ,M., STEVANOVIĆ,M.: *Analysis of the construction characteristics of automatic domestic production rifles for the purpose of equipping units of the Serbian Army*, Serbian Journal of Engineering Management, Vol. 5, No. 1, 2020, pp. 40 - 49.

[4] JOKIĆ,Ž., DELIBAŠIĆ,B., KOMLJENOVIĆ,S.: *Application of the VIKOR method in the selection of caliber for automatic rifles for the purpose of introduction into operational use in Serbian Army units*, Vojno delo, Vol. 70, no. 6, 2019, pp. 200 - 221.

[5] RADOVANOVIĆ,M., SAMOPJAN,M., STEVANOVIĆ,M.: *Application of AHP - VIKOR method of multicriteria decision making for selection of automatic rifle of domestic production, Ljubiša Papić (ed.), 11th DQM International* Conference Life Cycle Engineering and Management ICDQM - 2020 , The Research Center of Dependability and Quality Management, Prijevor, 2020, pp. 303-311.

[6] JENKINS,S.T., LOWREY,D.S.: *A Comparative Analysis Of Current And Planned Small Arms Weapon Systems*, MBA Professional Report, Naval Postgraduate School Monterey, California, USA, 2004.

[7] BOŽANIĆ,D., RANĐELOVIĆ,A., RADOVANOVIĆ,M., TEŠIĆ,D.: *A hybrid LBWA - IR-MAIRCA multi-criteria decision-making model for determination of constructive elements of weapons*, Facta Universitatis series: Mechanical Engineering, Vol.18, No.3, 2020, pp.399 - 418.

[8] JOKIĆ,Ž., BOŽANIĆ,D., PAMUČAR,D.: *Selection of fire position of mortar units using LBWA and Fuzzy MABAC model*, Operational research in Engineering Sciences: Theory and Applications, Vol 4, No. 1, 2021, pp. 115-135.

[9] PAMUČAR,D ĆIROVIĆ,G., BOŽANIĆ,D.: *Application of interval valued fuzzy-rough numbers in multi-criteria decision making*: The IVFRN-MAIRCA model, Yugoslav Journal of Operations Research, Vol. 29, No. 2, 2019, pp. 221-247.

[10] STOILOVA,S.: *An Integrated Multi-Criteria Approach for Planning Railway Passenger Transport in the Case of Uncertainty*. Symmetry, Vol. 12, No. 6: 949, 2020.

[11] BOŽANIĆ,D., JURIŠIĆ,D., ERKIĆ,D.: *LBWA – Z-MAIRCA model supporting decision making in the army*, Operational Research in Engineering Sciences: Theory and Applications, Vol. 3, No. 2, 2020, pp. 87-110.

[12] BADI,I., ABDULSHAHED, A.: Ranking the Libyan airlines by using full consistency method (FUCOM) and analytical hierarchy process (AHP), Operational Research in Engineering Sciences: Theory and Applications, Vol.2, No. 1, 2019, pp. 1-14.

[13] KOMAZEC,N., PETROVIĆ,A.: *Application of the AHP-VIKOR hybrid model in media selection for informing of endangered in emergency situations*, Operational Research in Engineering Sciences: Theory and Applications, Vol. 2, No. 2, 2019, pp. 12-23.

[14] SENNAROGLU,B., CELEBI,G.V.: (2018). *A military airport location selection by AHP integrated PROMETHEE and VIKOR methods.* Transportation Research Part D: Transport and Environment, 59, 160-173.

[15] TEŠIĆ,D., BOŽANIĆ,D.: *Application of the MAIRCA method in the selection of the location for crossing tanks under water*, Tehnika, Vol. 68, No. 6, 2018, pp. 860-867.

[16] RANĐELOVIĆ,A., LAZAREVIĆ,O.: *Description geometry and the rules of infantry weapon shooting*, in Miodrag Nestorovic (ed.), 25th National and 2nd International Scientific Conference moNGeometrija 2010, Faculty of Architecture in Belgrade, Belgrade, 2010, pp. 606-621.

[17] KOKELJ,T., RANĐELOVIĆ,A.: *Shooting Theory*, Global Security, Belgrade, 2018.

[18] RADOVANOVIĆ,M., RANĐELOVIĆ,A., BLAGOJEVIĆ,A., REPIĆ,P.: *Rectification accuracy of long range 12.7 mm m93 rifle scope*, Ljubiša Papić (ed.), 7th DQM International Conference Life Cycle Engineering and Management ICDQM - 2016, The Research Center of Dependability and Quality Management, Prijevor, 2016, pp. 535–540.

[19] RANĐELOVIĆ,A., RADOVANOVIĆ,M., STEVANOVIĆ,M.: *Influence of rectification of 12.7 mm M93 long-range rifle sights on execution of tasks in anti-terrorist operation*, Ljubisa Papic (ed.), 22nd International DQM Conference Quality and Reliability Management ICDQM - 2019, Research Center for Quality and Reliability Management, Prijevor, 2019, pp. 345-351.

[20] REGODIĆ,D.: *External Ballistics*, Ministry of Education, Military Academy, Belgrade, 2006.

[21] Military Lexicon, VIZ, Belgrade, 1981.

[22] RADOVANOVIĆ,M.: *Analysis of the accuracy of rectification of sights of a long-range sniper rifle 12.7 mm M93*, - final work, Military Academy, Belgrade, 2016.

[23] BEKAVAC,I., ĆIRIĆ,R.: *Ballistics for Secondary Military Schools of the Army and Artillery Units*, VIZ, Belgrade, 1979.

[24] DINIĆ,O.: *Teorija gađanja pešadijskim naoružanjem*, SSNO, Beograd, 1984.

[25] SAATY,T.L.: *Analytic hierarchy process*, McGraw-Hill, New York, 1980.

[26] BOŽANIĆ,D., PAMUČAR,D., BOJANIĆ,D.: *Modification of the analytical hierarchy process (AHP) method using fuzzy logic: Fuzzy AHP approach as a support to the decision making process concerning engagement of the group for additional hindering*, Serbian Journal of Management , Vol.10, No.1, 2015, pp.151-171.

[27] BOŽANIĆ,D., TEŠIĆ,D., MILIĆEVIĆ,J.: *A hybrid fuzzy AHP-MABAC model: Application in the Serbian Army - The selection of the location for deep wading as a technique of crossing the river by tanks*, Decision Making: Applications in Management and Engineering, Vol. 1, no. 1, 2018, pp. 143-164

[28] PETROVIĆ,I., GORDIĆ,M., KANKARAŠ,M.: *Fazi – AHP pristup u vrednovanjukriterijumazaizborraketnogsistemazaprotivvazduhoplovna dejstva*, Vojno delo, Vol. 70, No. 2, 2018, pp 298-308.

[29] STANKOVIĆ,M., GLADOVIĆ,P., POPOVIĆ,V.: *Determining the importance of traffic accessibility criteria using fuzzy AHP and rough AHP method*, Decision Making: Applications in Management and Engineering, Vol. 2, no. 1, 2019, pp. 86-104.

[30] RADOVANOVIĆ,M., RANĐELOVIĆ,A., JOKIĆ,Ž.: *Application of hybrid model fuzzy AHP - VIKOR in selection of the most efficient procedure for rectification of the optical sight of the long-range rifle*, Decision Making: Applications in Management and Engineering, Vol . 3, no. 2, 2020, pp.131-148.

[31] CHATTERJEE,P., STEVIĆ,Ž.: *A two-phase fuzzy AHP - fuzzy TOPSIS model for supplier evaluation in manufacturing environment*, Operational Research in Engineering Sciences: Theory and Applications, Vol. 2, no. 1, 2019, pp. 72-90.

[32] RADOVANOVIĆ,M., STEVANOVIĆ,M.: *Analysis of anti-armor missile systems using the hybrid model AHP-VIKOR method of multi-criteria decision-making*, Serbian Journal of Engineering Management, Vol. 6, No. 1, 2021, pp. 37 - 44.

[33] JANKOVIĆ,A., POPOVIĆ,M.: *Methods for assigning weights to decision makers in group AHP decision-making* , Decision Making: Applications in Management and Engineering, Vol. 2, no. 1, 2019, pp. 147-165.

[34] Expert Choice Software, EC2000, 2000. Expert Choice Inc., Pittsburg, USA

[35] SRĐEVIĆ,B., ZORANOVIĆ,T.: *AHP in group decision making with complete and incomplete information*, SYMOPIS 2003, Herceg Novi, 2003, pp. 727-730.

[36] MILIĆ,A., PAMUČAR,D., BOŽANIĆ,D.: *Multicriteria decision making as a support to project management (military operations)*, Branko Savić (ed) 13th International Conference "Risk and Security Engineering", Kopaonik, 2018, pp. 25-30.

[37] ČUPIĆ,M., SUKNOVIĆ,M.: *Decision Making*, FON, Belgrade, 2010.

[38] SRĐEVIĆ,Z., SRĐEVIĆ,B., POTKONJAK,S., ZORANOVIĆ,T.: *allocation of the land on the crop plants and in irrigation drainage is multicriterially approach using the Analytic Hierarchy Process (AHP), and the land reclamation of farm equipment*, Faculty of Agriculture, USA, 2003.Samed Karović, Conditionality of the organizational and formation structure of artillery units to support the introduction of modern technologies, Military Academy, Belgrade, 2006.

[39] KAROVIĆ,S., PUŠARA,M., RISTIĆ,V., KOMAZEC,N.: *Analytical Hierarchical Process as a Support to the Decision-Making of the Engagement of Forces in the Defense Operation*, (SYM-OP-IS 2011), Zlatibor, 2011, pp. 588-591.

[40] MILIĆ,M., KAROVIĆ,S., SLAVKOVIĆ,R.: *Evaluation of a model for making minefields using the Analytical Hierarchical Process*, SYM-OP-IS 2014, Divčibare, 2014, pp. 469 - 472.

[41] RADOVANOVIĆ,M., RANĐELOVIĆ,A., MILIĆ,A.: *Comparative analysis of anti-armor systems using the AHP method*, Vojno delo, Vol. 71, no. 7, 2019, pp. 234-250.

[42] NIKOLIĆ,I., BOROVIĆ,S.: *Multicriteria Optimization*, Military School Center, Belgrade, 1996.

[43] BOROVIĆ,S., MILIĆEVIĆ,M.: *Collection of Tasks from Selected Areas of Operational Research*, SCHONID, UNID, VA, Belgrade, 2001.

Received: 06.07.2021.
Accepted: 25.08.2021.

Analiza tačnosti i preciznosti gađanja automatskim puškama domaće proizvodnje primenom AHP metode

U radu je prikazan izbor najtačnije i najpreciznije automatske puške, kao značajnog naoružanja prvenstveno za realizaciju borbenih zadataka vojske. Veličina slike rasturanja pogodaka i njena udaljenost od cilja opredeljuju stepen tačnosti i preciznosti automatske puške. Navedeni pokazatelji određuju verovatnoću pogađanja koja utiče na efikasnost rešavanja vatrenih zadataka automatskom puškom. Složenost problema uslovljena je različitim taktičko-tehničkim karakteristikama automatskih pušaka i različitim rezultatima gađanjanja. U radu su prikazani i opisani rezultati gađanja automatskih pušaka domaće proizvodnje i to: AP 7,62 mm M70 AB2, AP M21 5,56 mm, AP M17 6,5 mm. Primenom metode AHP izvršen je proračun težinskih koeficijenata kriterijuma. Primenom metode AHP izvršena je analiza tačnosti i preciznosti gađanja automatskih pušaka i izveden zaključak o pušci koja ima najbolje rezultate u zavisnosti od daljine gađanja. Dobijeni rezultati omogućavaju definisanje predloga za opremanjem jedinica Vojske Srbije adekvatnom automatskom puškom.

Ključne reči: **automatska puška, višekriterijumsko odlučivanje, metoda AHP, tačnost, preciznost, naoružanje.**