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SELECTION OF UNPLOYED AIRCRAFT FOR TRAINING OF SMALL-RANGE AIRCRAFT DEFENSE SYSTEM AHP - TOPSIS OPTIMIZATION METHODS

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Abstract: The article solves the problem of more efficient and economical training of combat crews on short range air defense systems. The training so far is based on the use of conventional means, which require engagement of a large number of people, expensive equipment, long-term planning and spending a lot of time and space. The use of unmanned aerial vehicles - drones, greatly saves all these resources. Our mathematical model, using the methods of multicriteria decision-making - Analytical Hierarchical Processes (AHP) and optimization - The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), determines the weighting coefficients and then ranks alternatives or, the ranking for drone selection, which would replace classical means for training and coaching so meeting all parameters and characteristics of the training itself and the training equipment. The methods first prioritize the selection criteria, and then, based on their importance, concretize the solution among the offered alternatives.

Keywords: Unmanned Aircraft, Drone, AHP, TOPSIS, Optimization, Training.

MSC: 90B85, 90C26.

1. INTRODUCTION

A Continuous training of a crew or an individual on short-range air defense systems (ADS) is a very important segment of the entire system of protection of units and facilities from air attacks. Whether it is a matter of military or non-military threats (terrorism, paramilitary formations), every important object or a unit on the move has within itself means and air defense systems for immediate defense and protection.

According to the current regulations, in order to perform training and coaching, it is necessary to spend large resources. Starting from manpower, through landfills, facilities, to the technical devices and equipment themself, the time and financial costs for this activity have become uneconomical. For the training of a crew or an individual on the simplest short-range air defense systems, it is necessary to hire 3 to 4 people. Training grounds and facilities where such trainings are performed, in a given period cannot be used simultaneously for any other purpose, so they are 100

The problem becomes complex by a multitude of factors, unrelated to the human factor. There is a great influence of weather conditions, time of day, air temperature, condition and amount of clouds. The condition of the equipment used for training and coaching is also an important factor, which can prolong this activity beyond the planned time and space, to the extent that the training and coaching is not even performed. All these factors affect the functional ability of crew or an individual of short-range air defense systems to the extent of being not usable.

The use of Usage of unmanned aerial vehicles, drones, solves many of these problems. The shortcomings of the previous practice are practically eliminated, when it comes to temporal-spatial influences, mentioned as an obstacle to training in the previous part of the text. The required number of people on training grounds and terrains is being reduced, so as the spatial dimensions of the training ground, high - risk units are being disengaged, such as aircraft, tractors, meta- simulators of targets in the air. The training and coaching planning sector is relieved. The effects that would be achieved by introducing new funds into the current practice are positive on most issues.

In the literature so far, drones have not been specially treated as a means to be used in training. Some of the areas covered cover are their use in reconnaissance of nuclear-chemical accidents [14], as well as their wider application in units of the Serbian Army [16]. Also, they are mentioned in the text on the use of drones in combat operations [23], [32] and [34]. We can learn a lot about drones as a means of education from the following articles: [6], [1] and [24].

The methods that will be used in this paper are generally accepted and have been used for a long time to optimize and solve such and similar problems. The AHP method has been used in a large number of papers such as: [20];[9];[10] ; [17]; [3]. The situation is similar with the TOPSIS method: [25]; [26]; [7]; [18] ; [21]; [13]. In recent times, various modifications of these methods are often used ([33]; [12]; [3];).

The terminology used today for unmanned aircraft is not yet fully defined. The most often name used in the development of these devices in numerous professional publications was "Unmanned Aerial Vehicle" (UAV), which in direct translation would mean "aerial vehicle without crew". In the Republic of Serbia, the term "unmanned aircraft" (UA) is the most often used in our paper. We accept as a permissible definition of this type of aircraft, the following : "Unmanned aircraft is a type of aircraft whose flight is controlled by a computer on board the aircraft or whose flight is remotely controlled by ground operators [31].

In order to approximate the selection method of UA for training of a crew or an individual crew or an individual on short range air defense systems, the categorization of UA, methodology for evaluating criteria for selection of optimal UA using AHP method, calculation of prioritization of criteria for selecting UA, as well as selection of UA using optimization methods are presented AHP and TOPSIS.

2. CONVENTIONAL WAY OF TRAINING PROBLEMS

Within the basic training of anti-aircraft shooters, on short-range air defense systems, it is necessary to fulfill several steps, so that the results achieved by training and coaching give the desired effect. Previous trainings on short-range systems were performed on specialized simulators intended for that purpose, and as an imitator of the target, IR radiation sources were used, placed in the air in the form of projectiles from the "signal gun" [19].

In order to carry out this procedure correctly, the first step is to find a terrain or training grounds, where the action can be performed so that it is not dangerous for other structures, facilities, population and living world. The next condition is the allocation of airspace due to the ballistic characteristics of projectiles simulating IR radiation. Engagement of fire, pyrotechnic, and medical teams is also a component of planning this activity.

One of the aggravating circumstances is the procurement of training equipment itself, such as signal bullets - projectiles, which are the main source of IR radiation, so that the short-range air defense system can identify the target, perform the intervention and only the training shooting. In be in time, , as a parameter for the realization of training activities, it is important to note that each projectile has a short flight time, for which the server on the simulator must do the entire procedure for shooting.

There are training procedures on short-range, more complex type air defense systems. They require the engagement of aviation units, which means aircraft technicians, pilots, airspace allocation by the airspace allocation department at the Serbia and Montenegro Air Traffic Services Agency (SMATSA).To be realized, these trainings, in addition to human ones, require large material resources realization.

Exercises with an unmanned aircraft would solve most of the problems above. Preparation time would be minimized as it would not be necessary to go out on a special field or training ground. Training time would be limited solely by the autonomy of the aircraft's flight, and material costs would be minimized. The number of repetitions would also be practically unlimited. The problem solved in this article is the evaluation of criteria for selecting the optimal unmanned aircraft, which would replace the conventional means in the process of training the servers (operators) within the means of short-range air defense.

3. CATEGORIZATION OF UNMANNED AIRCRAFT AND DEFINITION OF CRITERIA

To approach the selection of UA for the task of training servers (operators) on short-range air defense systems, it is necessary to consider its basic parameters. If UA from the same category is considered, there are certain restrictions refering to altitude and flight speed, range, payload, possibility of installing sensors (IR emitters), cost price, etc. In order to consider and select the optimal UA model, an analysis of their classification according to different methodologies was performed, such as: NATO (North Atlantic Treaty Organization), EUROCONTROL (European Organization for the Safety of Air Navigation) and UAVS (Unmanned Aerial Vehicle Systems Association). The classification of UA in the NATO alliance is shown in Table 1.

The class	Category	Level of applica-tion	Maximum flight altitude (ft)	Range (km)	Basic command support	Representative
Class 1 under 150kg	Micro ¡ 2kg	Team	up to 200	5	Team	Black Widow
	Mini 2-20kg	Company level unit	up to 3000	25	Company level unit	Raven
	Little ¿ 20kg	Tactical squad	up to 5000	50	Batalion	Hermes 90
Class 2 500kg to 600kg	Tactical	Tactical formation	up to 10000	200	Brigade	Hermes 450
Class 3 over 600kg	Operational	Operational	up to 45000	Unlimited	Headquarters	Predator
	Strategic	Strategic	up to 65000	Unlimited	Joint Staff	Global Hawk

Tablica 1: Classification of UA according to NATO methodology (www.globalsecurity.org)

The classification of UA according to the EUROCONTROL methodology is shown in Table 2.

Class	Maximum weight (kg)	Reach	Range (km)	Maximum flight altitude (ft)
Class 0	Under 25	Small range	Under 10	1000
Class 1	25 – 500	Short range	10 – 100	15000
Class 2	501 – 2000	Medium range	100 – 500	30000
Class 3	Over 2000	Long range	Over 500	Over 30000

Tablica 2: Classification of UA according to EUROCONTROL methodology (www.eurocontrol.int)

According to the Association of Unmanned Aerial Vehicles (UAVS), UAs are classified as shown in Table 3.

Category name	Abbreviation	The mass of the aircraft (kg)	Range (km)	Maximum flight altitude (m)	Flight autonomy (h)
micro	micro	¡5	¡10	250	1
mini	mini	25-150	¡10	150-300	¡2
small range	CR	25-150	10-30	3000	2-4
short range	SR	50-250	30-70	3000	3-6
middle range	MR	up to 1250	70-200	5000	6-10
durable medium range	MRE	up to 1250	¿500	8000	10-18

Tablica 3: Classification of UA according to UAVS methodology (Kolarek, 2010)

In the Republic of Serbia, the flight of unmanned aircraft is regulated by the Rulebook on Unmanned Aircraft. The same Rulebook classifies UA according to three criteria: the method of management, the purpose, and the operating mass and performance (Ordinance on unmanned aerial vehicles, 2015). According to the method of management, UA is divided into:

- unmanaged UAs;
- automatically managed UAs;
- Remotely controlled UAs, operated by a pilot located in a station or cabin on the vehicle.

According to the purpose, UAs are classified into:

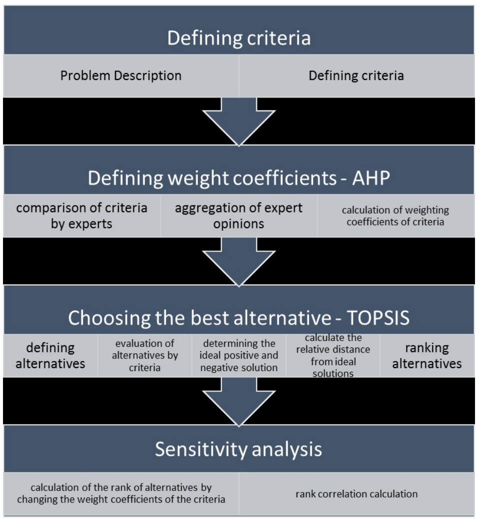
- UAs used for economic purposes;
- UAs used for non-economic purposes (aeronautical models and UAs used for scientific, educational and other purposes).

Considering the purpose of UA for the training of crew or an individual on short-range air defense systems, the analysis of UA from all categories was performed. To select the optimal UA model, in accordance with the described categorizations, the criteria for the selection of the optimal model of the unmanned aircraft were determined. Based on the data collected from experts, the criteria for selecting the optimal unmanned aircraft in this paper are as follows: payload (C1), flight speed (C2), price - economy (C3), flight altitude (C4) and flight autonomy - flight duration (C5).

Load capacity is a characteristic that defines the amount of load that UA can lift. It is important because the training implies that UA imitates a source of IR radiation of certain wavelengths. Therefore, a certain device that will radiate a given thermal characteristic must be "attached" to the aircraft. As it is about training on air defense systems, the aircraft must reach certain flight altitudes, so we introduce a characteristic - flight altitude. Autonomy, flight duration without landing is a feature, which describes how long the training can last, without being unnecessarily interrupted due to charging the aircraft batteries.

4. MATHEMATICAL MODEL

The evaluation of previously defined criteria was performed using the AHP (The Analytical Hierarchy Process) method, which is suitable for optimizing the solution of highly structured problems. After prioritization of the criteria, the optimal unmanned aerial vehicle was selected using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method [13];



Slika 1: Steps in solving the problem

4.1. EVALUATION AND PRIORITIZATION OF CRITERIA - AHP METHOD

Data were obtained by questionnaire from 20 respondents. Previously, the questionnaire was adjusted to Satie's evaluation scale [30]. By applying the Satie scale, all elements of the comparison can have one of 17 values [1/9, 9]. Using the Satie scale, in the first step, the respondents compared all the criteria by pairs and thus determined the dominance of one criterion in relation to another. By pairwise comparison of criteria, individual matrices of pairwise comparison were obtained for each examinee. Respondents determined the values of the mutual value of the pair comparison only for the upper part of the triangle of the individual matrix of the pair comparison. The elements of the individual pairwise matrix for K-th subjects were obtained using the following formula:

$$a_{ij}^{(k)} = \frac{1}{a_{ij}^{(k)}} \tag{1}$$

if $i \neq j$, for the elements in the lower part of the triangle matrix.

$$a_{ij}^{(k)} = 1, if, i = j, k \tag{2}$$

for elements diagonally.

Using the previous formulas, all values of individual matrices of pair comparison were obtained for each of the K examinees individually (having in mind the way of calculating the values of the elements, in this matrix they are positive, symmetric, and reciprocal). The elements of a unique matrix of pairwise comparison are obtained by arithmetic averaging of the elements of individual steam comparison matrices using the following formula:

$$a_{ij} = \sum_{k=1}^{n} \frac{a_{ij}^{k}}{n} \tag{3}$$

number of respondents.

Based on the values from the unique matrix of pairwise comparison, the matrix of normalized values was calculated using the following formula ([30]; [22]).

$$a_{ij}{}' = \frac{a_{ij}}{\sum\limits_{i=1}^{n} a_{ij}} \tag{4}$$

where - represents the value of the element from the unique pairwise matrix.

Using the following formula, the values of relative weights were obtained:

$$w_i = \frac{\sum\limits_{j=1}^{n} a_{ij}'}{n} \tag{5}$$

The degree of consistency of the results was determined using the following formulas ([30]):

$$CR = \frac{CI}{RI} \tag{6}$$

where: CI - consistency index

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{7}$$

and λ_{max} - maximum eigenvalue of the comparison matrix, which is obtained as follows:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \lambda_i \tag{8}$$

$$\lambda_i = \frac{b_i}{w_i} \tag{9}$$

$$\begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \tag{10}$$

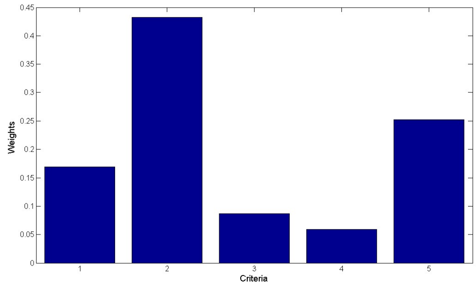
RI - random index, which depends on the number of rows - column of the matrix n ([30]). For n = 2, RI = 0, for n = 3 follows RI = 0.52, for n = 4 follows RI = 0.89, for n = 5 follows RI = 1.11, for n = 6 follows RI = 1 , 25.

If $CR \leq 0.10$ then the result is consistent.

In this case, the data on the mutual comparison of the criteria were collected using an adapted questionnaire (the questionnaire was adapted to the AHP method - Satie scale). In the first step, the aggregation of the obtained data was performed by applying formula 3. In this way, an average matrix of mutual comparison of criteria (preference matrix) was obtained. The value of the weights of the criteria was obtained by applying formula 5 (Table 4 and Figure 2).

Criteria	C1	C2	C3	C4	C5	Wi	Rank
C1	1	0.31	2.60	3.75	0.60	0.169	3
C2	3.85	1	4.35	5.85	2.25	0.432	1
C3	0.40	0.25	1	1.90	0.32	0.087	4
C4	0.29	0.20	0.58	1	0.27	0.059	5
C5	2.32	0.50	3.25	4.05	1	0.252	2

Tablica 4: Average matrix of pairwise comparisons and criteria' weights



Slika 2: criterias weights

The degree of consistency was calculated using formulas 6-9 and is 0.09 (CR = 0.09). Given that the value obtained is less than 0.1, the results obtained are consistent.

4.2. OPTIMIZATION OF ALTERNATIVES BY TOPSIS METHOD

The TOPSIS method is based on ranking of alternatives in relation to the ideal and negative ideal solution. The ideal solution maximizes the benefit criteria and minimizes the cost criteria. A negative ideal solution maximizes cost criteria and minimizes benefit criteria. The offered alternatives are ranked based on the distance from the ideal solutions. The optimal alternative is the one that is closest in the euclidean sense to the ideal, and the furthest from the negative ideal alternative ([13]). When applying this method, in the first step is formed an initial decision matrix, after which will be performed normalization ([13]):

$$x_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{n} r_{ij}^2}} \tag{11}$$

In the next step, the normalized values of the matrix are multiplied by the values of the relative weights of the criteria, and in that way a weight-normalized matrix with the elements V_{ij} is obtained. The ideal solution is the following vector ([13]):

$$A^* = \{(max\ v_{ij}, j \in G), (min\ v_{ij}, j \in G^-)\} = \{v_1^*, v_2^*, \dots v_m^*\} \tag{12}$$

.

The negative ideal solution is the following vector:

$$A^- = \{(max\ v_{ij}, j \in G), (min\ v_{ij}, j \in G^-)\} = \{v_1^-, v_2^-, \dots v_m^-\} \tag{13}$$

. where G - criteria that are maximized, and G^{-} - criteria that are minimized.

The next step is to determine the distances of the alternatives from the ideal ones using the following formulas ([13]):

$$S_i^* = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^*\right)^2},\ i = 1, \ldots, n \tag{14}$$

.

$$S_i^- = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^-\right)^2},\ i = 1, \ldots, n \tag{15}$$

.

In the next step, the relative proximity to the ideal solution is determined for each alternative ([13]):

$$Q_i^* = \frac{S_i^-}{\left(S_i^* + S_i^-\right)},\ 0 \leq Q_i^* \leq 1 \tag{16}$$

.

In the last step, the alternatives are ranked. The optimal alternative is the one with the highest value ([13]). Table 5 shows the characteristics of the offered alternatives (unmanned aerial vehicles) by criteria.

Criteria	C1 benefit	C2 benefit	C3 cost	C4 benefit	C5 benefit
A1	48	10	4559	500	45
A2	35	10	2650	500	45
A3	20	10	6100	500	42
A4	1,5	20	3000	1000	50
A5	3	10	7250	500	50
A6	6	35	2700	3500	80
A7	5	15	2500	1000	55
A8	17	14	11300	500	110
A9	8	20	5600	3000	95
A10	32	25	37000	5000	360
A11	25	10	10000	500	90
A12	19	14	8300	500	300

Tablica 5: Values of alternatives per criteria (initial decision matrix)

The normalized matrix was obtained using formula 11 (Table 6).

Criteria	C1 benefit	C2 benefit	C3 cost	C4 benefit	C5 benefit
A1	0.60	0,16	0.11	0,07	0.09
A2	0.44	0.16	0.06	0.07	0.09
A3	0.25	0.16	0.14	0.07	0.08
A4	0.02	0.33	0.07	0.14	0.10
A5	0.04	0.16	0.17	0.07	0.10
A6	0.08	0.57	0.06	0.49	0.15
A7	0.06	0.24	0.06	0.14	0.11
A8	0.21	0.23	0.26	0.07	0.21
A9	0.10	0.33	0.13	0.42	0.18
A10	0.40	0.41	0.86	0.71	0.69
A11	0.31	0.16	0.23	0.07	0.17
A12	0.24	0.23	0.19	0.07	0.58

Tablica 6: Values of alternatives per criteria (Normalized decision matrix)

After calculating the weight normalized matrix, the ideal and negative ideal solution were determined (Table 7).

Criteria	C1 benefit	C2 benefit	C3 cost	C4 benefit	C5 benefit
A1	0.102	0.070	0.009	0.004	0.022
A2	0.074	0.070	0.005	0.004	0.022
A3	0.042	0.070	0.012	0.004	0.020
A4	0.003	0.141	0.006	0.008	0.024
A5	0.006	0.070	0.015	0.004	0.024
A6	0.013	0.246	0.005	0.029	0.039
A7	0.011	0.106	0.005	0.008	0.027
A8	0.036	0.099	0.023	0.004	0.053
A9	0.01	0.141	0.011	0.025	0.046
A10	0.068	0.176	0.075	0.042	0.175
A11	0.053	0.070	0.020	0.004	0.044
A12	0.040	0.099	0.017	0.004	0.146
A*	0.102	0.246	0.005	0.042	0.175
A-	0.003	0.070	0.075	0.004	0.020

Tablica 7: Values of alternatives per criteria (Weighted normalized decision matrix and ideal and negative ideal solutions)

By applying formulas 14-16, relative proximities to the ideal solution were obtained and the ranking of alternatives was performed (Table 8).

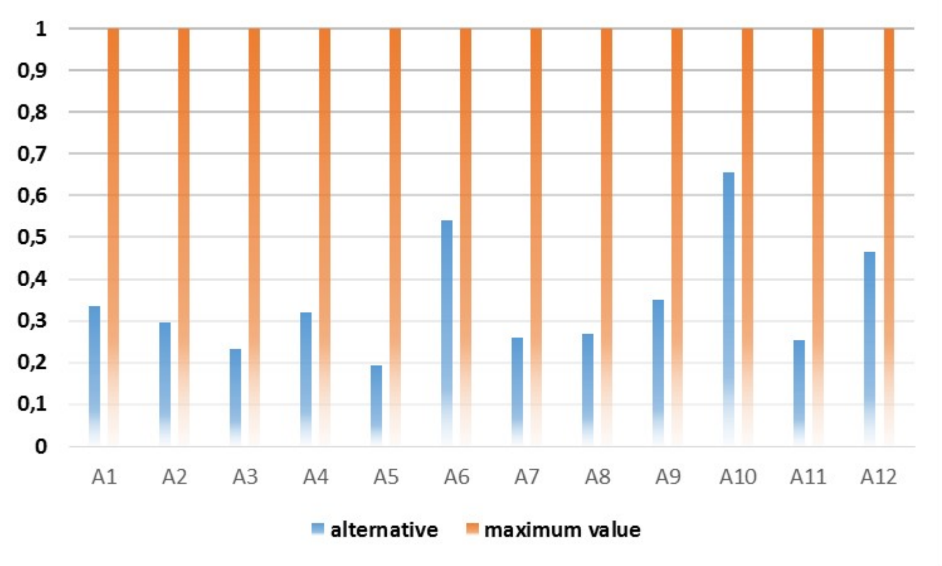
	Si*	Si-	Qi*	Ranking
Ranking A1	0.236	0.119	0.334	5
A2	0.238	0.100	0.295	7
A3	0.245	0.074	0.232	11
A4	0.211	0.099	0.319	6
A5	0.254	0.061	0.193	12
A6	0.163	0.192	0.541	2
A7	0.226	0.079	0.259	9
A8	0.207	0.076	0.268	8
A9	0.188	0.102	0.351	4
A10	0.105	0.202	0.657	1
A11	0.229	0.078	0.254	10
A12	0.168	0.146	0.466	3

Tablica 8: Rank of alternative

Based on the previous table, a graph of alternatives according to the rank of the most optimal to less optimal solutions was obtained, in relation to the ideal value (Figure 3).

4.3. SENSITIVITY ANALYSIS

In order to check the validity of the obtained results in the ranking of alternatives, it is necessary to perform an analysis of the sensitivity of the TOPSIS method to changes in parameters, which can lead to large deviations in obtained results. The model of changing the weight coefficients of the criteria is most often used for this procedure. This approach in sensitivity analysis has been presented in a large number of papers, such as: [8]; [5]; [28]; [11]; [15]; [4]; [2]. In this paper, changes in weight coefficients were made through 10 scenarios. It is planned that the criterion, which carries the highest weight (C2), from the initial value, is reduced by 10%, and this difference is correctly distributed to the remaining four criteria (C1, C3, C4 and C5). S1 is the initial value, also the first scenario, and



Slika 3: Rankings alternatives

then the scenarios go in order to S10, as the final one, where criterion C2 is at a minimum. (Table 9).

Table 9. Scenarios by criteria

Criteria	C1	C2	C3	C4	C5
S1	0.170	0,428	0,088	0,059	0,254
S2	0.183	0,384	0,094	0,064	0,273
S3	0.196	0,341	0,101	0,068	0,292
S4	0.209	0,298	0,108	0,073	0,311
S5	0.222	0,255	0,114	0,077	0,331
S6	0,235	0,212	0,121	0,082	0,350
S7	0,247	0,168	0,127	0,086	0,369
S8	0,260	0,125	0,134	0,091	0,388
S9	0,273	0,082	0,141	0,095	0,407
S10	0,286	0,039	0,147	0,100	0,426

Tablica 9: Scenarios by criteria

After determining the new weights of the criteria, through ten scenarios, one scenario at a time is returned to the calculation of the rank of alternatives (using formulas 14-16), where data on the ranks of all alternatives are obtained for each scenario separately (Table 10).

Alternatives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A1	1A12
S1	5	7	11	6	12	2	9	8	4	1	10	3
S2	4	6	11	7	12	2	10	8	5	1	9	3
S3	4	5	10	8	12	3	11	9	6	1	7	2
S4	4	5	10	9	12	3	11	8	6	1	7	2
S5	4	5	9	10	12	3	11	8	7	1	6	2
S6	3	5	9	11	12	4	10	7	8	1	6	2
S7	3	4	9	11	12	5	10	7	8	1	6	2
S8	3	4	9	11	12	7	10	6	8	1	5	2
S9	3	4	9	11	12	8	10	6	7	1	5	2
S10	3	4	9	11	12	8	10	6	7	1	5	2

Tablica 10: Alternatives ranged by scenarios

What can be noticed, based on the previous Table, is that, despite the change of parameters in the system for optimization and decision making, it is certain that the best alternative (A10) is always in the first place, the worst alternative (A5) is always in the last place, and other alternatives slightly change their rank positions. Alternative A6 shows a slightly larger deviation because the only criterion in which it had an advantage (C2), compared to the other criteria, is less and less difficult in each subsequent scenario. As a result, its rank decreases rapidly and goes from position 2 to position 8. Along with the sensitivity analysis through the scenario, the Spearman coefficient was calculated, ie., an indicator of the correlation of all alternatives in relation to each other, through each scenario. It is calculated based on the ranking of results and determining the difference in ranks, based on the formula:

$$r = 1 - \frac{6 \sum D^2}{N(N^2 - 1)} \tag{17}$$

.

where D is the difference in ranks and N is the sample size.

The value of Spearman's correlation of the criteria ranges from -1 to 1. The value of the coefficient determines the strength of the relation, and the sign determines the direction of the relation. When interpreting the strength of the correlation, the following scale can be used to compare the connections of higher ranks (correlation in the range from 0 to 1, positive correlation) (Table 11):

Coefficient	Correlation
0-0,19	very weak
0,2-0,39	weak
0,4-0,59	middle
0,6-0,79	strong
0,8-1,0	Very strong

Tablica 11: Spyrman's criteria scale

Comparing all alternatives through defined scenarios, Spearman's coefficient ranged from minimum rmin = 0.60 to maximum rmax = 1.00, so the correlations between alternatives are strong or very strong, and it can be confirmed that the TOPSIS method has been successfully implemented in solving the problem and is valid for its solution. Correlations, in which the coefficient ranged between 0.60 and 0.70, were those alternatives that generally had an advantage according to only one stronger criterion or had an advantage in the case of criteria that did not carry sufficient weight.

5. DISCUSSION - CONCLUSION

Based on the initial problem, evaluation of criteria and optimization calculation, a solution is obtained in the form of ranked alternatives. Alternatives were selected from the real environment, and the criteria were evaluated and ranked by experts, based on a survey.

Based on the expert selection of the importance of the criteria, we determined their rank by the AHP method. As a conclusion of this part of the calculation, the result turned out to be the most important criterion C2 - UA flight speed. The importance of this criterion is that the speed of UA also determines the angular speed of its movement in relation to the means by which the air defense is performed during the training. If the speed is too low (10 m / s and less), the training would not give real results, ie. would not be effective. Criterion C5 - flight duration, or flight autonomy, is also one of the most important criterion, according to the conclusion of the experts. The training on the air defense system is an ongoing process and the results will be poor if the training time is short and intermittent. Therefore, this criterion is important to be as valuable as possible.

Criteria C1 - payload, C3 - cost price and C4 - flight altitude UA, in that order, form a group of less important criteria compared to the first two described. The aircraft should carry any source of IR simulators (sources of heat radiation) because certain short-range air defense systems are aimed at such targets. These heat sources can weigh from a few grams to a maximum of 1 Kg, with its own power supply, which most UAs can meet. The cost price, in this case, is one of the less important criteria for choosing an aircraft, because switching to training in this way saves a lot of money and resources, both material and human. The least important criterion, the flight altitude of UA is in the last place because the flight altitude does not affect the possibility of performing training. Namely, at much shorter distances and less space for training servers on the short-range air defense system, with the help of UA, the height at which they should be does not exceed 50m - 150m.

In the next step, the ten offered alternatives were ranked by the TOPSIS optimization method, after which we obtained the most optimal solution, ie. the most optimal UA, which would make the training on short-range air defense systems more acceptable in every sense. In this way, it is possible to reduce the complexity of the conventional way of training in terms of time, space and consumption of material and human resources.

Optimization by the TOPSIS method, as the best ranked alternative, was offered by UA, which also has the best characteristics of the most important criteria C2 and C5. Flight speed and autonomy, with the two best ranked alternatives are A10 - 25 m/s, and A6 - 35 m/s, while flight autonomy with A10 – 360 min, and with A6 – 80 min. Although lower ranked, the criteria C1, C3, and C4 in these two alternatives are not negligible either. The payload is high, the altitude is also high, while the cost is slightly higher, but the experts put it only in the fourth place, considering that training on short-range air defense systems would save much more money with this innovative method.

Methods of multi-criteria decision-making and optimization, when used in conjunction, for calculations of the application of modern technologies in training and coaching, can provide great benefits. This way of thinking can modernize the process of education, decision-making and command. The positive effects are primarily reflected in the more rational use of time and space as one of the most expensive resources of today, and then in the saving of material and human resources. By including UA in the training crew or an individual on short-range air defense systems, could show the results of all these effects in practice.

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