UDK: 167.7,623.746-519:355.1
doi: 10.5937/str2102026R COSATI: 03-10, 15-03

Application of the Fuzzy AHP -VIKOR Hybrid Model in the Selection of an Unmanned Aircraft for the Needs of Tactical Units of the Armed Forces

Marko Radovanović[1)]
Aleksandar Petrovski [2)]
Vinko Žindrašič [3)]
Aca Ranđelović [3)]

Unmanned aerial vehicles represent an indispensable segment in the range of weapons of both military and police units. The expansion in development of unmanned aerial vehicles for both commercial and military purposes has created a need for constant improvement of drones and anti-drone means. A wide range of possibilities opens up a wide range of uses for them. The paper presents the choice of an unmanned aerial vehicle as an important combat system for the needs of tactical units of the army and police. The complexity of the problem is conditioned by various tactical - technical and economic characteristics of unmanned aerial vehicles, it has conditioned the use of different methods of multicriteria decision making.

A hybrid model of multicriteria decision making fuzzy AHP - VIKOR was used to select the unmanned aerial vehicle for the needs of tactical units. Criteria of importance for the selection of an unmanned aerial vehicle for the needs of tactical units have been defined on the basis of which the most optimal solution (unmanned aerial vehicle) has been selected. The criteria are defined on the basis of tactical-technical and economic characteristics of unmanned aerial vehicles. The calculation of the weight coefficients of the defined criteria was performed using the fuzzy AHP method, while the selection of the drone (the most favorable alternative) based on the defined criteria was performed using the VIKOR method. The obtained result represents the starting point for further research and implementation of unmanned aerial vehicles in tactical units of the army and police.

Key words: **Unmanned Aerial Vehicle (UAV), Drone, Unmanned Combat Aircraft Vehicle (UCAV), Fuzzy AHP, VIKOR, multi-criteria decision making.**

Introduction

THE tendency to create modern, better equipped and more efficient military and police forces in all countries of the world is growing as well as the need for the use of drones as one of the most important combat systems. Unmanned aerial vehicles with a wide range of use in different conditions and different operating environment are the means of increasing the efficiency of military and police units.

The term UAV has a broad meaning, it means a system with a motor that is remotely controlled by the operator or it is a system that has a certain level of autonomy (control is done using communication software, and often uses artificial intelligence and different types of sensors), which can be used once or repeatedly and can carry deadly or non-lethal cargo and transmit data in real time. It is a synthesis of the means and devices necessary to manage it. They differ in purpose, construction characteristics (shape, dimensions, weight, payload, maximum flight altitude, maximum range, flight time, speed, etc.) of the environment in which they are used, the energy source with which they are driven. Depending on the purpose, they can be used in different environment such as land, water, air and space, and a wide range of possibilities has created a condition for application in defense and security (for the needs of the army and police - original purpose). agriculture, construction, traffic, trade, communication, science, medicine, research, architecture, video and photography, geology, forestry, mining, oceanography, environmental management, sports, mapping, etc. The term drone is more general than the term unmanned aerial vehicle, because all unmanned aerial vehicles can be called drones, while a drone does not necessarily have to be an unmanned aerial vehicle. A comparative analysis of unmanned aerial vehicles was performed in this paper.

A wide range of possibilities of unmanned aerial vehicles provides the possibility of using unmanned aerial vehicles for: shooting, photography, monitoring, tracking [1], reconnaissance [2], detection, attack on certain means and facilities, combat with other drones, transporting different cargo [3], protection of humankind and facilities, etc. These functions provide the possibility of using UAVs in various military and police units [4]. A detailed classification of drones was performed by Hasanalian and Abdelkefi in the paper [5], Yaacoub, Noura, Salman and Chehab in paper [6]. Petrovski and Radovanović in paper [7] defined the term drone as well as the detailed classification of drones shown in Fig.1. [7].

1) Army Brigade, Serbian Armed Forces, Dunavska 33, Novi Sad, SERBIA
2) University “Goce Delchev” - Shtip, Military academy "General Mihailo Apostolski" – Skopje, Vasko Karangelevski, Republic of North Macedonia
3) University of Defence, Military Academy, Veljka Lukića Kurjaka 33, 11000 Belgrade, SERBIA
Correspondence to: Radovanović Marko, e-mail: markoradovanovicgdb@yahoo.com

There are objective needs for the implementation of UAVs, the implementation which would provide an adequate support to the military and police units in conducting various operations. The final selection of the most optimal solution and their implementation in the tactical units of the army and police would significantly improve three key capabilities: *the ability to command, the ability to use information space, and the ability to use forces effectively.*

It is possible to find a large number of UAVs on the market today, with different features and different purposes (application in agriculture, medicine, transport, architecture, meteorology, photography, army, police, etc.) [8]. A large number of police and military units in the world have a certain model of UAV in their armament. The military and police requirements for the characteristics of UAVs for use in different types of operations are very uneven. Based on the above, the goal was set to choose the most favorable alternative (UAV) which, according to its characteristics in largely meets the needs of army and police tactical units. The results of the research can be used in further implementation of UAVs for the needs of tactical units of the army and police.

Figure 1. Classification of drones [7]

Literature analysis

The paper analyzes military drones for the needs of tactical units of the army and police. According to the literature that was available to the authors, there are a number of works by foreign authors who used the method of multi-criteria decision-making to select drones for different needs showing the selection of the optimal unmanned aerial vehicle for precision agriculture using the AHP method and the Expert choice 2000 software [9]. Žnidaršič et al. [10] show several types of drones and anti-drone means for implementation in the units of the Serbian Army. Liu & Chan use the fuzzy Analytic Network Process (ANP) method to analyze the weights of the quality indicators of drone recording and photography services [11]. Radovanović et al. demonstrate the possibility of using civilian drones in the protection and monitoring of the land security zone [1]. Milić et al. analyze the possibility of using drones in operations in urban environment [2]. Karaşan & Kaya apply the TOPSIS method to select the most efficient drone control technology [12]. Kovač et al. use the spherical fuzzy MARCOS method, they evaluate drone-based urban logistics concepts [13].

The complexity of drone selection has necessitated the application of a hybrid model of multi-criteria decision making. Due to the specifics of the problem, the research has defined a hybrid model composed of two methods: fuzzy AHP (Analytical Hierarchical Process) and VIKOR (VIšekriterijumsko KOmpromisno Rangiranje) methods.

The paper presents a model that selects the most optimal solution (UAV) in relation to the given criteria. The aim of this paper is to enable the selection of the most optimal solution through the application of multi-criteria decision-making methods in order to implement it in the tactical units of the army and police.

Research methods

The hybrid model, used to solve the problem of choosing an unmanned aerial vehicle for the needs of tactical units of the army and police, was defined by a combination of fuzzy AHP and VIKOR methods of multi-criteria decision-making. This part of the paper describes the methods used in the paper. The fuzzy AHP method was used to determine the weighting coefficients for the given criteria, while the VIKOR method was used to select the most optimal solution (unmanned aerial vehicles). The data used in the research were obtained on the basis of available literature and content analysis. Fig.2 shows the phases through which this model was realized.

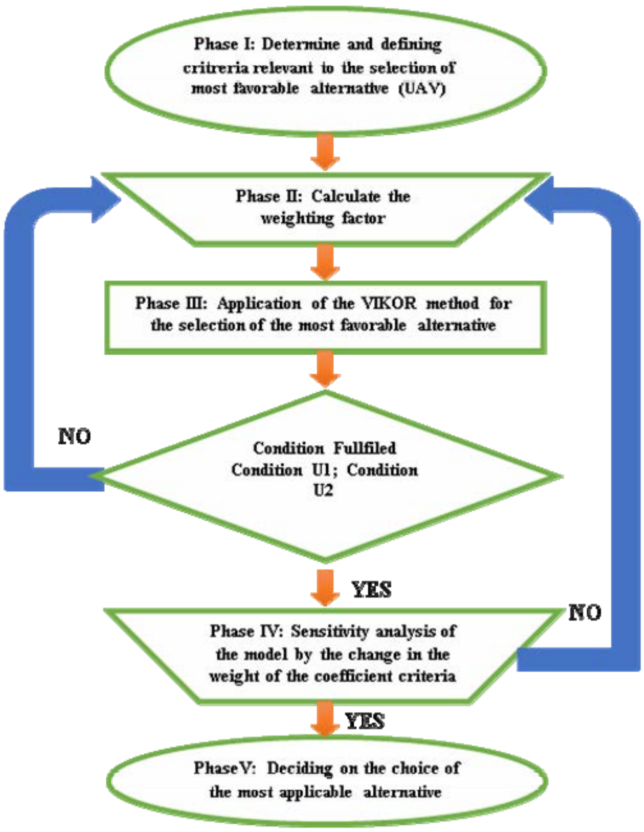

Figure 2. Algorithm of application of hybrid model fuzzy AHP - VIKOR

Description of fuzzy AHP method

The AHP method was developed by Thomas Saaty [14]. To date, this method has undergone a number of modifications [15, 16, 17, 18, 19, 20, 21, 22, 23, 24], but in some cases it is still used in its original form [25, 26, 27, 28, 29, 30].

Analytical hierarchical process is a method based on decomposition of a complex problem into a hierarchy, with the goal at the top, criteria, sub-criteria and alternatives at the levels and sublevels of the hierarchy [14]. For comparisons in pairs, which is the basis of the AHP method, the Saaty scale is usually used, Table 1. The comparison in pairs leads to the initial decision matrices. The Saaty scale is most commonly used to determine the weighting coefficients of the criteria [31], but can also be used to rank alternatives.

Table 1. Saaty scale for comparison in pairs

Standard values	Definition	Inverse values
1	Same meaning	1
3	Weak dominance	1/3
5	Strong dominance	1/5
7	Very strong dominance	1/7
9	Absolute dominance	1/9
2, 4, 6, 8	Intermediate values	1/2, 1/4, 1/6, 1/8

Very often when taking values from the Saaty scale in the pairwise comparison process, decision makers hesitate between the values they will assign to a particular comparison. In other words, it happens that they are not sure of the comparison they are making. Due to the above, various modifications of the Saaty scale are often made. One of them is the application of fuzzy numbers [32].

There are different approaches in the fuzzification of the Saaty scale, and in principle they can be divided into two groups: sharp (hard) and soft fuzzification. The fuzzification can be done with different types of fuzzy numbers, and is most often done using a triangular fuzzy number, Fig.3.

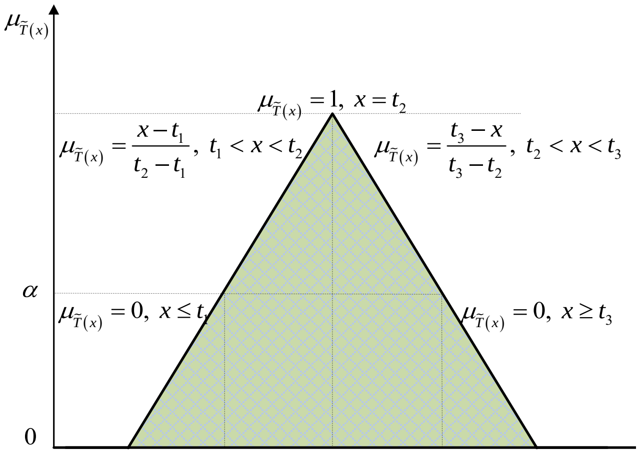

Figure 3. Triangular fuzzy number T [27]

The "sharp" fuzzification means that for a fuzzy number a $T = (t_1, t_2, t_3)$ confidence interval is predetermined, i.e., it is predefined that the value of the fuzzy number will not be greater than t_3, not less than t_1 [15]. Based on a predefined fuzzy Saaty scale, a comparison is made in pairs. In soft fuzzification, the confidence interval of the values in the Saaty scale is not predetermined, but is defined during the decision-making process, based on additional parameters.

The definition of the weight coefficients of the criteria in this paper was performed by applying the phased Saaty scale presented in the papers [16, 17, 33, 34, 35].

The starting elements of this fuzzification are [34]:

1. introduction of fuzzy numbers instead of classic numbers of the Saaty scale,
2. introduction of the degree of confidence of decision makers / analysts / experts (DM / A / E) in the statements they give when comparing in pairs - γ.

The degree of confidence γ is defined at the level of each comparison in pairs. The value of the degree of confidence belongs to the interval $\gamma \in [0,1]$, where $\gamma = 1$ describes the absolute confidence of DM / A / E in the defined comparison. Decreased confidence of the decision maker / analyst in what has been done the comparison is accompanied by a decrease in the degree of confidence γ_{ji}. Forms for calculating fuzzy numbers are given in Table 2.

Table 2. Fuzzification of the Saaty scale using the degree of confidence [34]

Definition	Standard values	Fuzzy number	Inverse values of a fuzzy number
Same meaning	1	(1, 1, 1)	(1, 1, 1)
Weak dominance	3	$(3\gamma_{ji}, 3, (2-\gamma_{ji})3)$	$(1/3\gamma_{ji}, 1/3, 1/(2-\gamma_{ji})3)$
Strong dominance	5	$(5\gamma_{ji}, 5, (2-\gamma_{ji})5)$	$(1/5\gamma_{ji}, 1/5, 1/(2-\gamma_{ji})5)$
Very strong dominance	7	$(7\gamma_{ji}, 7, (2-\gamma_{ji})7)$	$(1/7\gamma_{ji}, 1/7, 1/(2-\gamma_{ji})7)$
Absolute dominance	9	$(9\gamma_{ji}, 9, (2-\gamma_{ji})9)$	$(1/9\gamma_{ji}, 1/9, 1/(2-\gamma_{ji})9)$
Intermedi-ate values	2, 4, 6, 8	$(x\gamma_{ji}, x, (2-\gamma_{ji})x)$ $x = 2,4,6,8$	$(1/x\gamma_{ji}, 1/x, 1/(2-\gamma_{ji})x)$ $x = 2,4,6,8$

An example of the appearance of a fuzzy number with different degrees of confidence is given in Fig.4. For example, the value of low dominance from the Saaty scale and degrees of confidence were taken $\gamma = 1$, $\gamma = 0.7$ and $\gamma = 0.3$.

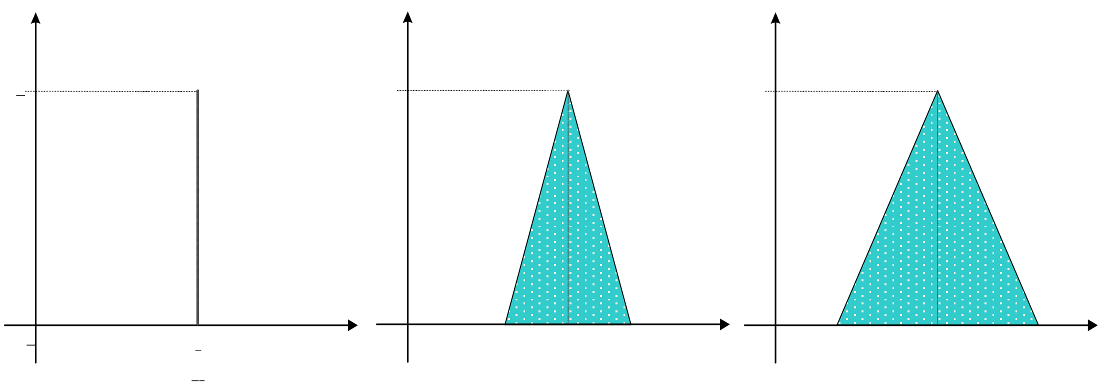

Figure 4. Dependence of a fuzzy number on the degree of confidence [34]

By introducing different values of the degree of confidence, the left and right distributions of fuzzy comparisons change according to the expression

$$\tilde{T}=(t_1,t_2,t_3)=\begin{Bmatrix} t_1=\lambda t_2, & t_1\le t_2, & t_1,t_2\in[1/9,9] \\ t_2=t_2, & & t_2\in[1/9,9] \\ t_3=(2-\gamma)t_2, & t_3\le t_2, & t_2,t_3\in[1/9,9] \end{Bmatrix} \quad (1)$$

where the value of t_2 represents the value of the linguistic expression from the classical Saaty scale, which in the fuzzy number has a maximum affiliation t_2=1.

Fuzzy number $\tilde{T}=(t_1,t_2,t_3)=(x\gamma,x,(2-\gamma)x),\ x\in[1,9]$ is defined by expressions [34]:

$$t_1=x\gamma=\begin{Bmatrix} x\gamma & \forall 1\le x\gamma\le x \\ 1 & \forall x\gamma<1 \end{Bmatrix} \quad (2)$$

$$t_2=x,\ \forall x\in[1,9] \quad (3)$$

$$t_2=(2-\gamma)x,\ \forall x\in[1,9] \quad (4)$$

Inverse fuzzy number $T^{-1}=(1/t_3,\,1/t_2,\,1/t_1)=(1/(2-\gamma_{ji})x,\,1/\gamma_{ji}x),\ x\in[1,9]$ is defined as [34]:

$$1/t_3=1/(2-\gamma_{ji})x=\begin{Bmatrix} 1/(2-\gamma_{ji})x, & \forall 1/(2-\gamma_{ji})x<1 \\ 1, & \forall 1/(2-\gamma_{ji})x\ge 1 \end{Bmatrix} \quad (5)$$

$$1/t_2=1/\gamma_{ji}x,\ \forall 1/x\in[1,9] \quad (6)$$

$$1/t_1=1/\gamma_{ji}x,\ \forall 1/x\in[1,9] \quad (7)$$

Accordingly, the initial decision matrix has the following form [15]:

$$A=\begin{matrix} & K_1 & K_2 & \cdots & K_n \\ K & a_{11};\gamma_{11} & a_{12};\gamma_{12} & \cdots & a_{1n};\gamma_{1n} \\ K_2 & a_{21};\gamma_{21} & a_{22};\gamma_{22} & \cdots & a_{2n};\gamma_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ K_n & a_{n1};\gamma_{n1} & a_{n2};\gamma_{n2} & \cdots & a_{nn};\gamma_{nn} \end{matrix} \quad (8)$$

where is $\gamma_{ji}=\gamma_{ij}$. Reaching the final results implies further application of the standard steps of the AHP method. At the end of the application, the fuzzy number is converted to a real number. Numerous methods are used for this procedure [31].

Some of the well-known terms for defuzzification are [35, 38, 39]:

$$A=((t_3-t_1)+(t_2-t_1))/3+t_1 \quad (9)$$

$$A=[\lambda t_3+t_2+(1-\lambda)t_1]/2 \quad (10)$$

where λ represents an index of optimism, which can be described as the belief/attitude of DO in risk in decision making. Most often, the optimism index is 0, 0.5 or 1, which corresponds to the pessimistic, average or optimistic view of the decision maker [40].

Description VIKOR method

VIKOR (Multi-Criteria-Compromise Ranking) is a method of multi-criteria decision-making whose use is very common. It was developed by Serafim Opricović in 1986 [41]. It is suitable for solving various decision-making problems. It is especially emphasized for situations where criteria of a quantitative nature prevail.

The VIKOR method starts from the "boundary" forms of Lp - metrics, where the choice of the solution that is closest to the ideal is made. The presented metric represents the distance between the ideal point F^* and the point $F(x)$ in the space of criterion functions [40]. Minimizing this metric determines a compromise solution. As a measure of the distance from the ideal point, the following is used:

$$L_p(F*,F)=\left\{\sum\nolimits_{j=1}^{n}\left[f_j^*-f_j(x)\right]^p\right\}^{\frac{1}{p}},\ 1\le p\le\infty \quad (11)$$

The VIKOR method has been applied in a large number of papers in its original form [35, 42, 43, 44, 45] but also in fuzzy [46, 47, 48, 49, 50] and rough [51, 52, 53, 54] environment.

When applying the VIKOR method, the following terms are used:
- n - number of criteria
- m - number of alternatives for multicriteria ranking
- f_{ij} – the values of the i-th criterion function for the j-th alternative,
- w_j - weight of the j-th criterion function,
- the weight of the strategy, meeting most of the criteria,
- i - ordinal number of the alternative, i = 1, ..., m.,
- j - ordinal number of criteria, j = 1, ..., n,
- Q_i - measure for multicriteria ranking and - and alternatives

For each alternative, there are Q_i values, after which the alternative with the lowest value is selected. The measure for multicriteria ranking of the i-th action (Q_i) is calculated according to the expression [55]:

$$Q_i=v\times QS_i+(1-v)\times QR_i \quad (12)$$

where is:

$$QS_i=\frac{S_i-S*}{S^- -S^*} \quad (13)$$

$$QR_i=\frac{R_i-R^*}{R^- -R^*} \quad (14)$$

By calculating the QS_i, QR_i, and Q_i sizes for each alternative, it is possible to form three independent rankings. Size QS_i, is a measure of deviation that shows the requirement for maximum group benefit (first ranking list) Size QR_i is a measure of deviation that shows the requirement to minimize the maximum distance of an alternative from the "ideal" alternative (second ranking list). Q_i size represents the establishment of a compromise ranking list that combines QS_i and QR_i sizes (third ranking list). By choosing a smaller or larger value for v (the weight of strategies to meet most criteria), the decision maker can favor the influence of QS_i size or QR_i size in the compromise ranking list. For example, higher values for v (v> 0.5) indicate that the decision maker gives greater relative importance to the strategy of meeting most of the criteria. Modeling the preferential dependence of criteria usually includes the weights of individual criteria. If weight values are specified $w_1,w_2,...,w_n$, multicriteria ranking by VIKOR method is realized using the measure Si and R_i. In the previous terms, the labels used have the following meanings:

$$S_i=\sum_{j=1}^{n}W_j\frac{f_j^*-f_{ij}}{f_j^*-f_j^-}=\sum_{j=1}^{n}w_j\times d_{ij},\ i=1,2,...,m \quad (15)$$

$$R_i = \max_j w_j \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} = \max_j w_j \times d_{ij}, \; i = 1, 2, ..., m \quad (16)$$

$$S^* = \max_i S_i$$

$$S^- = \max_j S_i$$

$$R^* = \max_i R_i$$

$$R^- = \max_j R_i$$

$$f_j^* = \max_i f_{ij}, \quad j = 1, 2, \; ...., n$$

$$f_j^- = \max_i f_{ij}, \quad j = 1, 2, \; ...., n$$

Alternative a_i is better than alternative a_k according to j – tom criterion, if:

- $f_{ij} > f_{kj}$ (for max f_j, that is, when there is a criterion maximum requirement),
- $f_{ij} < f_{kj}$ (for min f_j, that is, when there is a criterion minimum requirement).

In multi-criteria ranking by the VIKOR method, alternative ai is better than alternative a_k (in total, according to all criteria), if: $Q_i < Q_k$. A compromise ranking list for the value $v = 0.5$ is taken as an acceptable ranking list according to the VIKOR method.

The *f* an alternative is in the first position on such a compromising ranking list, it still does not mean that this alternative is considered the best. In order for an alternative to be adopted as the best, it must be the first on the compromise ranking list and meet two conditions: condition U1 and condition U2 [34].

Condition U1

The first alternative on the compromise ranking list for the value $v = 0.5$, must have a "sufficient advantage" over the action from the next position. The "advantage" is calculated as the difference of the measure Q_i for the value $v = 0.5$. Alternative a 'has a "sufficient advantage" over the next a "from the ranking list, if fulfilled:

$$Q(a') - Q(a'') \geq DQ \quad (17)$$

$$DQ = \min\left(0.25 \frac{1}{m-1}\right) \quad (18)$$

where is:
DQ - “sufficient advantage” threshold
m - number of alternatives,
0.25 - size of the “sufficient advantage” threshold which limits the threshold for cases with a small number of alternatives

Condition U2

The first alternative on the compromise ranking list for the value $v = 0.5$, must have a "sufficiently stable" first position with a change in weight *v*. The first alternative on the compromise ranking list has a "sufficiently stable" position, if it meets at least one of the following conditions:

- has the first position on the ranking list according to *QS*,
- has the first position on the ranking list according to *QR*,
- has the first position on the ranking list according to *Q* for v =0,25 and v = 0,75.

If the first action from the compromise ranking list does not meet one or both conditions (U1 and U2), it is considered that it is not "sufficiently" better than the action from the second position and possibly some more actions. In such cases, a set of compromise solutions is formed, which consists of the first, second and possibly some other actions (third, fourth ...). If the first action does not meet the condition U2 only, then only the first and second actions are included in the set of compromise solutions. However, if the first action does not meet condition U1 (or both conditions, both U1 and U2), then the set of compromise solutions contains actions from the compromise ranking list to the action that meets condition U1, i.e., to the one over which the first action has a "sufficient advantage" via *DQ*.

The results of the **VIKOR** method are:

- Ranking of lists according to QS_i, QR_i and Q_i measures,
- A set of compromise solutions (in case the conditions U1 and / or U2 are not met).
- These results represent the basis for deciding and adopting the final solution (multi-criteria optimal solution).

Defining criteria, alternatives and calculation of weighting coefficients of criteria

In the first phase of the application of the hybrid model of multi-criteria decision-making, the definition of criteria that influence the selection of the most optimal solution (UAV) was performed, for the needs of defense and security systems, i.e., for the needs of military and police tactical units. When defining the criteria for the selection of UAV, it is necessary to include all relevant characteristics of the system to be optimized, which is further important for defining the weight coefficients of the criteria. The criteria are defined on the basis of a study of the available literature and the views of experts. The following six criteria were identified on the basis of which the UAV comparison was performed. We emphasize that the experts stated that there is no need to establish subcriteria, which is why all criteria present the same hierarchical level in the analysis.

*Maximum speed (*C1*)* is a criterion that is of the beneficial type (higher values are more desirable). Maximum speed directly affects the efficiency of the system, increasing the maximum speed increases the efficiency of UAV. Higher maximum speed directly affects the increase of maneuvering and tactical capabilities of UAV, which also directly increases their efficiency. Higher speed provides the possibility of a faster response to a new situation. The stated criterion is of a numerical character and is expressed in the distance traveled in a unit of time (km/h) and represents one of the most important criteria when choosing a drone.

*Flight autonomy (*C2*)* represents the total time that an aircraft can spend in flight, without recharging energy. The criterion is of the beneficial type. Greater flight autonomy increases the efficiency of the combat system and enables a longer time to complete the task, which is extremely important when the requirements are such that it is not possible to interrupt the task due to the replacement or replenishment of energy sources. The level of autonomy can vary from fully autonomous operation to full control by the remote operator. The difference in the concept of autonomy is the difference between automatic and autonomous systems. [56]. Flight autonomy is a criterion of a numerical character, expressed in a unit of time (h).

*Maximum range (*C3*)* represents the maximum distance to which the UAV can travel. The higher the maximum range, the higher the efficiency of UAVs, because it realizes the possibility of realizing long-range combat tasks. The higher maximum range allows the use of drones at different distances and allows the use of drones in the depths of enemy territory, which is more important for military than for police units. Like the previous criteria, this criterion is of the beneficial type, and is expressed in kilometers (km). A higher maximum range also increases the operator's protection from enemy action.

*Maximum flight altitude (*C4*)* is the maximum altitude at which the drone can be used. Higher maximum flight altitude opens greater opportunities for the use of UAV/drones and increases the efficiency of the combat system. The criterion expresses the requirement for maximization, and is expressed in meters (m).

*The price of one system (aircraft plus accompanying ground and reconnaissance equipment) (*C5*)* represents the total price to be paid for one UAV with accompanying equipment. The criterion is of economic character and "cost" type. The price of the system is expressed in US dollars (USD ($)). This criterion can also be expressed in another monetary currency. This criterion is important for choosing the most favorable solution due to the high price of tactical drones and the need for a large number of drones to equip tactical units of the army and police. The stated criterion is directly influenced by the economic power of the state. The financial stability of the state is inversely proportional to the importance of this criterion.

*Maximum payload weight (payload) (*C6*)* is an additional equipment (additional payload) that is placed on the UAV, based on which type, purpose and class of affiliation is characterized. For the needs of tactical units of the army and police, it is necessary for drones equipped with various types of cameras, sensors, weapons and other useful equipment. The stated criterion is of the "benefit" type, and is expressed in kilograms (kg) [2].

Using the fuzzy AHP method shown in the previous section, the weight coefficients of the criteria were determined. The weighting coefficients were calculated for each expert separately, and the obtained values were aggregated into one. The obtained weighting coefficients of the criteria are given in Table 3.

Table 3. Normalized criterion weights

Normalized criterion weights	
C_1	0.1024
C_2	0.3793
C_3	0.2488
C_4	0.1604
C_5	0.0434
C_6	0.0654

Research results

Today, a large number of countries in the world produce UAVs of various sizes and purposes, but a small number of those that can be armed (UCAV - Unmanned Combat Aerial Vehicle). Combat drones generally belong to the class of medium drones that usually fly at altitudes of about 3000 to 9000 meters and can stay in the air for 20 to 60 hours. These aircraft are usually powered by a reciprocating or turboprop engine in a thrust configuration, with modern electro-optical systems containing TV, thermal and IR cameras, laser markers and rangefinders, satellite navigation, data links, and some drones have radars. They usually carry at least two to four lethal means to act on targets on land and sea (some can carry much more).

The most complex and modern unmanned aerial vehicles come from the USA. Israel is one of the leading countries when it comes to the development of these aircraft, and in recent years, the People's Republic of China has made a big breakthrough on the UCAV market. Today, Russia, Turkey, Iran, Pakistan and a few other countries are working intensively on the development of armed drones and their small-scale lethal weapons. American armed drones like the MQ-9 "Reaper" are expensive, and they can only be bought by the closest allies, politically eligible as well as rich countries. For the needs of tactical units of the army and police, it is necessary to create a model for the selection of the most optimal solution, depending on the defined criteria, in order to implement a certain drone in these units. The analysis defines seven alternatives, i.e., seven unmanned aerial vehicles that are analyzed for the purpose of procurement and implementation in the defense and security system. All seven alternatives come from different manufacturers and from different countries.

Table 4 shows the initial decision matrix where the values of the criterion functions for each alternative are shown.

Tabela 4. Initial decision matrix

	C_1 (km/h) (max)	C_2 (h) (max)	C_3 (km) (max)	C_4 (m) (max)	C_5 (million $) (min)	C_6 (*kg*) (max)
	w=0.1024	w=0.3793	w=0.2488	w=0.1604	w=0.0434	w=0.0654
A1	256	12	200	4000	1	80
A2	216	20	200	6500	2	140
A3	150	8	300	5000	1	60
A4	176	20	300	5500	2	150
A5	224	15	300	5000	1,5	120
A6	200	20	250	6000	1,7	100
A7	252	30	250	4500	1,6	130

Using the expression 11-16, the final values of the alternatives were obtained, which is shown in Table 5.

Table 5. Calculated values for QS_i, QR_i, Q_i (v=0,5), Q_i (v=0,75), Q_i (v=0,25)

	QS_i	QR_i	Q_i (v=0,5)	Q_i (v=0,75)	Q_i (v=0,25)
A_1	1.000	0.725	0.862	0.931	0.794
A_2	0.450	0.481	0.465	0.458	0.473
A_3	0.730	1.000	0.865	0.798	0.933
A_4	0.126	0.175	0.151	0.138	0.163
A_5	0.279	0.519	0.399	0.339	0.459
A_6	0.322	0.175	0.249	0.285	0.212
A_7	0.000	0.000	0.000	0.000	0.000

The ranking of unmanned aerial vehicles was realized on the basis of the results shown in Table 5, and the ranking of alternatives is shown in Table 6.

Table 6. Rank alternative based QS_i, QR_i, Q_i

	QS_i	QR_i	Q_i (v=0,5)	Q_i (v=0,75)	Q_i (v=0,25)
A_1	7	6	6	7	6
A_2	5	4	5	5	5
A_3	6	7	7	6	7
A_4	2	2	2	2	2
A_5	3	5	4	4	4
A_6	4	2	3	3	3
A_7	1	1	1	1	1

Based on the results from Table 6, it is concluded that the most optimal solution is alternative A_7. In order for a certain alternative to be selected as the best, it is necessary to fulfill the conditions U1 and U2. Testing of condition U1 was performed, which was fulfilled because $Q(A_4) - Q(A_7) = 0{,}151 - 0{,}00 = 0{,}151 > DQ = 0{,}0345$.

Condition U2 is fulfilled because alternative A_7 has a "sufficiently stable first place" because it has the first position according to the ranking lists *QR*, *QS* and on the ranking list *Q* (*v*=0,25) and *Q* (*v*=0,75).

Considering that the subjectivity of decision makers is always present to a certain extent, when defining input parameters for calculating weight coefficients of criteria, it is necessary to minimize errors. In practical terms, through the last step of the model, errors in defining weighting the coefficient of the criterion, regardless of the method by which these weighting coefficients are determined.

Sensitivity analysis

Sensitivity analysis is the last step that needs to be applied. Sensitivity analysis is an important segment of the validation of results. It has been featured in a number of papers [57, 58, 59, 60, 61, 62, 63, 64]. Weak results of sensitivity analysis take the whole research process to the beginning [65]. There are different approaches to the sensitivity analysis of models; most often authors in their papers use sensitivity analysis by changing weight coefficients of the criteria [66]. This analysis implies evaluation of alternatives based on different weight coefficients of criteria, that is favoring one criterion in each scenario. In this research we defined seven scenarios, Table 7.

Table 7. Weight coefficients of criteria in different scenarios

Criteria	S-0	S-1	S-2	S-3	S-4	S-5	S-6	S-7
C1	0.102	0.400	0.120	0.120	0.120	0.120	0.120	0.166
C2	0.379	0.120	0.400	0.120	0.120	0.120	0.120	0.166
C3	0.249	0.120	0.120	0.400	0.120	0.120	0.120	0.166
C4	0.160	0.120	0.120	0.120	0.400	0.120	0.120	0.166
C5	0.043	0.120	0.120	0.120	0.120	0.400	0.120	0.166
C6	0.065	0.120	0.120	0.120	0.120	0.120	0.400	0.166

Rankings of alternatives obtained using different scenarios are shown in Table 8.

Table 8. Rankings of alternatives obtained using different scenarios

Alternative	S-0	S-1	S-2	S-3	S-4	S-5	S-6	S-7
A1	6	5	6	7	7	3	6	6
A2	5	4	5	6	4	7	4	5
A3	7	7	7	5	6	4	7	7
A4	2	6	3	3	3	6	3	4
A5	4	2	4	1	2	1	2	1
A6	3	3	2	4	1	5	5	3
A7	1	1	1	2	5	2	1	2

Obtained rankings, shown in Table 9, imply that favoring certain criteria affects the differences in rankings; this further implies that the developed model is sensitive to the changes of weight coefficients. Rankings of alternatives by different scenarios are visible in the graph below, Fig.5.

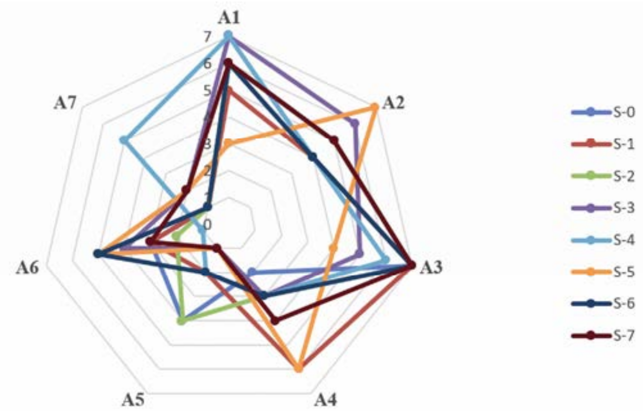

Figure 5. Graph of alternatives rankings by scenarios

The worst-ranked alternatives (A3, A1) in a large number of scenarios kept their rankings, as well as the best-ranked ones (A1, A5). However, even though the correlation between rankings seems pretty obvious, a serious analysis demands quantitative indicators. In that sense, we checked rankings correlation using the Spearman's rank coefficient [58]:

$$S = 1 - \frac{6\sum_{i=1}^{n} D_i^2}{n(n^2-1)} \quad (19)$$

where: S - the value of the Spirman coefficient; Di - the difference in the rank of the given element in vector w and the rank of the correspondent element in the reference vector; n - number of ranked elements. The values of the Spearman's coefficients range from -1 ("ideal negative correlation") up to 1 ("ideal positive correlation") [58].

In Table 9, one can see values of the Spearman's coefficients by comparing all scenarios to each other. In the first row of Table 9, when comparing scenario S-0 (values of weight coefficients obtained through research) to others we got values compared to the final ranking.

Table 9. Rankings of alternatives obtained using different scenarios

Alternative	S-0	S-1	S-2	S-3	S-4	S-5	S-6	S-7
S-0	1	0.607	0.964	0.679	0.500	0.071	0.821	0.750
S-1		1	0.714	0.571	0.393	0.500	0.750	0.857
S-2			1	0.643	0.571	0.107	0.750	0.786
S-3				1	0.679	0.500	0.786	0.857
S-4					1	-0.143	0.393	0.679
S-5						1	0.321	0.464
S-6							1	0.857
S-7								1

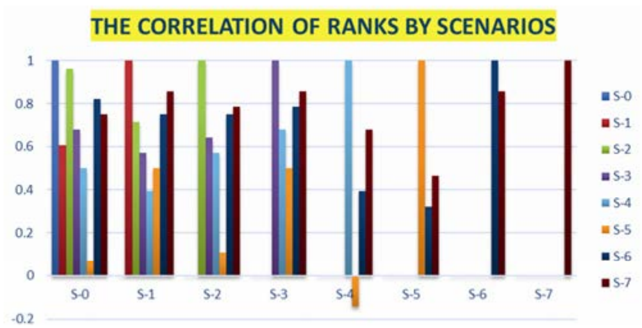

Figure 6. Graphical representation of the correlation of ranks by scenarios

From Table 9 and Fig.6, it is clear that the correlation of rankings by scenarios is very high. Certainly, the most important correlation of the ranks is between the S-0 scenario and others, where the value of the Spearman coefficient is usually above 0.600, which can be considered satisfactory. The lowest correlation of ranks is between scenarios S-4 and S-5 (-0.143), but it can be considered expected that there are lower correlations in situations where the weight coefficient of the criterion increases significantly, as is the case with criterion C5. Criterion C5 has the lowest weighting coefficient, significant favoring of this criterion leads to a negative value of correlation of ranks, and lower values of correlation with a given criterion. There are essentially no scenarios whose correlation tends to ideally uncorrelated ranks. This indicates that the fuzzy AHP - VIKOR model can lead to good solutions, even in cases where the weighting coefficients deviate from reality.

Conclusion

The development of unmanned aerial vehicles from the beginning of the XXI century, with their wide range of possibilities, opens the possibility of application in all spheres of society. Unmanned aerial vehicles are widely used in defense and security systems as well as for commercial purposes. The paper uses the fuzzy AHP-VIKOR model to select the most optimal solution (UAV) for the needs of equipping military and police units of the tactical level. In this way, a more detailed review of the presented problem was performed. The paper presents the phases of development and application of multicriteria decision making models. The criteria of importance for the selection of the model of unmanned aerial vehicle for the needs of tactical units of the army and police were defined and the calculation of the weight coefficients of the criteria was performed by the fuzzy AHP method. The selection of the most optimal compromise solution was realized by applying the VIKOR method of multi-criteria decision-making.

Alternative A7 stands out as the optimal solution from the analyzed characteristics of unmanned aerial vehicles in the previous part of the paper. The mentioned unmanned aerial vehicle represents the most modern and state-of-the-art scientific and technological solutions. The basic goal of such a high-tech tool is to prevent operational and tactical surprises. This alternative is equally effective in both military and police units.

The contribution of this paper is reflected in the selection of the most optimal unmanned aerial vehicle depending on the given criteria, whose implementation in tactical units of the army and police would significantly increase the efficiency of these units. We have also conducted sensitivity analysis of the model. The results obtained from the sensitivity analysis show that the output values (rankings of alternatives) change depending on the weight coefficients. On the other hand, changes in rankings while changing the weight coefficients of the criteria, demonstrated clearly the dominance of the first-ranked alternatives. Everything listed above implies that the model provides the same or similar results, regardless of possible minor errors that can occur in the process of defining the weight coefficients of the criteria, as a consequence of subjectivity of experts, that is, the decision-makers. The presented model can be further improved by a more detailed analysis of the criteria depending on the needs of tactical units of the army and police, by defining the additional criteria relevant to the selection of drones, defining more alternatives to UAVs and applying other methods of multicriteria analysis needs of the defense and security system.

Acknowledgements

This paper was written as 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] RADOVANOVIĆ,M., MILIĆ,A., RANĐELOVIĆ,A.: *Possibility of using drones in the protection of the Land Security Zone*, 15th International Conference on Risk and Security Engineering, Technical College of Vocational Studies in Novi Sad and the Faculty of Technical Sciences, Kopaonik, 2020, pp. 303 - 311.

[2] MILIĆ,A., RANĐELOVIĆ,A., RADOVANOVIĆ,M.: *Use of drones in operations in the urban environment*, 5th International Scientific conference Safety and crisis management – Theory and practise Safety for the future – SecMan 2019, Regional Association for Security and Crisis Management S4 GLOSEC Gobal security doo, 2019, Belgrade, pp. 124-130.

[3] HASSANALIAN, M.: *Conceptual design, bioinspiration, and multidisciplinary analysis of drones*, Thesis for: PhD, New Mexico State University, Las Cruces, New Mexico, USA, 2018, pp. 7-8.

[4] KRAKOWIAK,E.: *Unmanned Aerial Vehicles in the Security Service and as a New Tool in the Hands of Criminals*, Safety & Defense, 2018, Vol. 4, No. 1, pp. 31-36.

[5] HASSANALIAN,M., ABDELKEFI,A.: *Classifications, applications, and design challenges of drones: A review.* Progress in Aerospace Sciences, Vol 91, May 2017, pp. 99-131

[6] YAACOUB,J.P., NOURA,H., SALMAN,O., CHEHAB,A.: Security Analysis of Drones Systems: Attacks, Limitations, and Recommendations, Internet of Things, 2020, Vol.11, 100218.

[7] PETROVSKI,A., RADOVANOVIĆ,M.: *Application of detection reconnaissance technologies use by drones in collaboration with C4IRS for military interested*, Contemporary Macedonian Defence, 2021, Vol. 21, No. 40, pp. 117-126.

[8] BOUKOBERINEA,M.D., ZHOUB,Z., BENBOUZID,M.: *A Critical Review on Unmanned Aerial Vehicles Power Supply and Energy Management: Solutions, Strategies, and Prospects*, Applied Energy, December 2019, Vol. 255, 113823.

[9] PETKOVICS,I., SIMON,J., PETKOVICS,A., ČOVIĆ,Z.: *Selection of unmanned aerial vehicle for precision agriculture with multi-criteria decision- making algorithm*, 15th International Symposium on Intelligent Systems and Informatics (SISY), IEEE, Subotica, 2017, pp. 000151-000156

[10] ŽNIDARŠIČ,V., RADOVANOVIĆ,M., STEVANOVIĆ,D.: *Modeling the organizational implementation of a drone and counter-drone operator into the Serbian Armed Forces rifle section*, Vojno delo, Vol. 72, No. 3, 2020, pp. 84 -109.

[11] LIU,C.C., CHEN,J.J.: *Analysis of the Weights of Service Quality Indicators for Drone Filming and Photography by the Fuzzy Analytic Network Process*, Applied Sciences, 2019, Vol. 9, No. 6, 1236.

[12] KARAŞAN,A., KAYA,İ.: *Neutrosophic TOPSIS Method for Technology Evaluation of Unmanned Aerial Vehicles (UAVs),* Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making INFUS 2019. Advances in Intelligent Systems and Computing, Springer, Cham, 2020, Vol 1029, pp. 665-673.

[13] KOVAČ,M., TADIĆ,S., KRSTIĆ,M., BOUARIMA,B.,M.: *Novel Spherical Fuzzy MARCOS Method for Assessment of Drone-Based City Logistics Concepts,* Complexity, December 2021, Vol. 2021, Article ID: 2374955, pp. 1-17.

[14] SAATY,T.L.: *The analytic hierarchy process,* McGraw-Hill, New York, 1980.

[15] BOŽANIĆ,D., PAMUČAR,D., BOJANIĆ,D.: *Modification of the Analytic Hierarchy Process (AHP) Method using fuzzy logic: fuzzy AHP approach as a support to the decision-making process concerning the engagement of the Group for Additional Hindering*, Serbian Journal of Management, 2015, Vol. 10, No. 2, pp. 151-171.

[16] 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, 2018, Vol. 1, No. 1, pp. 143-164.

[17] BOŽANIĆ,D., PAMUČAR,D.: (2016*). Modification of the Saaty scale using a fuzzy number with variable check interval: Example of flood hazard assessment,* Conference of Analytical hierarchical process: Application in energy, protection of work and environment and education, Nis, 2016, pp. 79 - 99.

[18] PETROVIĆ,I., GORDIĆ,M., KANKARAŠ,M.: *Fuzzy - AHP approach in evaluating the criteria for selecting a missile system for anti - aircraft operations,* Vojno delo, 2018, Vol. 70, No. 2, pp. 298-308.

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

[20] 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, 2019, Vol. 2, No. 1, pp. 72-90.

[21] BOŽANIĆ,D., PAMUČAR,D., ĐOROVIĆB.: *Modification of Analytic Hierarchy Process (AHP) Method and its Application in the Defense Decision-making,* Tehnika, 2013, Vol. 68, No. 2, pp. 327-334

[22] BOŽANIĆ,D., PAMUČAR,D., KAROVIĆ,S.: *Use of the fuzzy AHP - MABAC hybrid model in ranking potential locations for preparing laying-up positions*, Vojnotehnički glasnik/Military Technical Courier, 2016, Vol. 64, No. 3, pp. 705-729

[23] PAMUČAR,D., BOŽANIĆ,D., KURTOV,D.*: Fuzzification of the Saaty's scale and a presentation of the hybrid fuzzy AHP-TOPSIS model: an example of the selection of a Brigade Artillery Group firing position in a defensive operation,* Vojnotehnički glasnik /Military Technical Courier, 2016, Vol. 64, No. 4, pp. 966-986

[24] BOŽANIĆ,D.: *Model of decision support in overcoming water obstacles in Army combat operations, (Only in Serbian: Model podrške odlučivanju pri savlađivanju vodenih prepreka u napadnoj operaciji Kopnene vojske),* doctoral dissertation, University of Defence in Belgrade, Military Academy, Belgrade, 2017.

[25] LUKOVAC,V., ZELIĆ DRAKULIĆ,S., TOMIĆ,M., LIU,F.: (2021). *Multicriteria approach to the selection of the trainingmodel of dangerous goods transport advisors in the Ministry of Defense and the Serbian Army*, Military Technical Courier/Vojnotehnički glasnik, 2021, Vol. 69, No. 4, pp. 828-851.

[26] RADOVANOVIĆ,M., RANĐELOVIĆ,A., MILIĆ,A.: *Comparative analysis of anti - armor systems using the AHP method,* Vojno delo, 2019, Vol. 69, No. 7, pp. 234 -250.

[27] RADOVANOVIĆ,M., STEVANOVIĆ,M.: *Analysis of the construction characteristics of automatic domestic production rifles*, Serbian Journal of Engineering Management, 2020, Vol. 5, No. 1, pp. 40 – 49.

[28] RANĐELOVIĆ,A., RADOVANOVIĆ,M., STEVANOVIĆ,M.: *Comparative analysis of anti-tank missile systems using the AHP method in order to equip units of the Serbian Army*, 22nd International DQM Conference on Quality and Reliability Management ICDQM-2019, Prijevor, Serbia, 2019, pp. 336-344.

[29] RADOVANOVIĆ,M., SAMOPJAN,M., STEVANOVIĆM.: *Application of AHP -VIKOR method of multicriteria decision making for selection of automatic rifle of domestic production*, 11th DQM International conference Life Cycle Engineering and Management ICDQM – 2020, Prijevor, Serbia, 2020, pp. 303 – 311,

[30] RADOVANOVIĆ, M., MILIĆ, A. & PETROVSKI, A.: *Analysis of accuracy and precision of shooting with home - made automatic rifles using the AHP method*, Scientific Technical Review, 2021, Vol.71, No.1, pp.30-37

[31] RADOVANOVIĆ,M., MILIĆ,A., 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, 2021, Vol. 6, No. 1, pp. 37-44.

[32] 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, 2019, Vol. 29, No. 2, pp. 221-247.

[33] PAMUČAR, D., BOŽANIĆ, D. & MILIĆ, A.: *Selection of a course of action by Obstacle Employment Group based on a fuzzy logic system* Yugoslav Journal of Operations Research, 2016, Vol. 26, No. 1, pp. 75-90.

[34] BOJANIĆ,D., KOVAČ,M., BOJANIĆ,M., RISTIĆ,V.: *Multi-criteria decision-making in A defensive operation of the guided anti-tank missile battery: an example of the hybrid model fuzzy AHP – MABAC*, Decision Making: Applications in Management and Engineering, 2018, Vol. 1, No. 1, pp. 51-66.

[35] BOBAR,Z., BOŽANIĆ,D., ĐURIĆ,K.A., PAMUČAR,D.: *Ranking and Assessment of the Efficiency of Social Media using the Fuzzy AHP-Z Number Model - Fuzzy MABAC,* Acta Polytechnica Hungarika, 2020, Vol. 17, No. 3, pp. 43-70.

[36] 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, 2020, Vol 3, No. 2, pp. 131-148

[37] HERRERA,F., MARTÍNEZ,L.: *An Approach for Combining Numerical and Linguistic Information based on the 2-tuple fuzzy linguistic representation model in Decision Making*, International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 2000, Vol. 8, 539-562.

[38] LIOU,T.S., WANG,M.J.: *Ranking fuzzy numbers with integral value. Fuzzy Sets and Systems*, 1992, Vol. 50, pp. 247-256.

[39] SEIFORD,L.M.: *The evolution of the state-of-art (1978-1995),* Journal of Productivity Analysis, 1996, Vol. 7, pp. 99-137.

[40] MILIĆEVIĆ,M.: *Ekspertsko ocenjivanje*, Medija centar „Odbrana“, Beograd, 2014.

[41] OPRICOVIĆ,S.: *Multicriteria optimization*, Scientific book, Belgrade, 1986.

[42] NISEL,S.: *An extended VIKOR method for ranking online graduate business programs,* International Journal of Information and Education Technology, 2014, Vol. 4, No. 1, pp. 103-107.

[43] KUO,M.S., LIANG,G.S.: *Combining VIKOR with gra techniques to evaluate service quality of airports under fuzzy environment,* Expert Systems with Applications, 2011, Vol. 38, No. 3, pp. 1304 -1312.

[44] OPRICOVIĆ, S. & TZENG, G. H.: *Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS,* European Journal of Operational Research, 2004, Vol. 156, No. 2, pp. 445-455.

[45] JOKIĆ,Ž., DELIBAŠIĆ,B., KOMLJENOVIĆ,S. *Application of the VIKOR method during the selection of calibers for automatic rifles in order to introduce them into operational use in the units of the Serbian Army*, Military Work, 2019. Vol. 71, No. 6, pp. 200-221.

[46] JABBAROVA,A.I.: *An Application of the Fuzzy VIKOR Method to an Investment Problem*, 14th International Conference on Theory and Application of Fuzzy Systems and Soft Computing – ICAFS-2020. ICAFS 2020, Advances in Intelligent Systems and Computing, Springer, Cham, 2021, Vol. 1306.

[47] SHARAF,I.M.: *Spherical Fuzzy VIKOR with SWAM and SWGM Operators for MCDM*, Decision Making with Spherical Fuzzy Sets. Studies in Fuzziness and Soft Computing, Springer, Cham, 2021, Vol. 392.

[48] CHATTERJEEA,P., CHAKRABORTYB, . A *comparative analysis of VIKOR method and its variants*, Decision Science Letters, 5/2016, 2016, pp. 469-486.

[49] INCE,O.: *Selection of an erp software system by using fuzzy VIKOR,* Proceedings of the 10th Joint Conference: Information Science, Salt Lake City, Utah, USA, 2007, Vol. 1708.

[50] SHEMSHADI,A., SHIRAZI,H., TOREIHI,M., TAROKHM.J.: *A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting*, An International Journal – Expert Systems with Applications, 2011, Vol. 38, No. 10, pp. 12160-12167.

[51] LI,X., SONG,W.: *A Rough VIKOR – Based QFD for Prioritizing Design Attributes of Product- Related Service*, Mathematical Problems in Engineering, 2016, pp. 1-11.

[52] WANG,Z., GAO,J., WANG,R., CHEN,K., GAO,Z., ZHENG,W.: *Failure Mode and Effects Analysis by Using the House of Reliability – Based Rough VIKOR Approach*, IEEE Transactions on Reliability, 2018, Vol. 67, No. 1, pp. 230-248.

[53] QI,J., HU,J., PENG,Y.: *Integrated rough VIKOR for customer-involved design concept evaluation combining with customers' preferences and designers' perceptions*, Advanced Engineering Informatics, 2020, Vol. 46, 101138.

[54] QI,J., HU,J., PENG,Y.: *Modified rough VIKOR based design concept evaluation method compatible with objective design and subjective preference factors,* Applied Soft Computing, 2021, Vol. 107, 107414.

[55] OPRICOVIĆ,S.: *Multicriteria system optimization in construction*. Faculty of Civil Engineering, Belgrade, 1998.

[56] CHANG,V., CHUNDURY,P., CHETTY,M.: *Spiders in the Sky: User Perceptions of Drones, Privacy, and Security*, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, Denver, New York 6768, 2017, pp. 6765 – 6776 .

[57] 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, 2021, Vol. 4, No. 1, pp. 115-135.

[58] 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, 2020, Vol. 18, No. 3, pp. 399-418.

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

[60] BOŽANIĆ,D., KAROVIĆ,S., PAMUČAR,D.: *Adaptive Neural Network for the Selection of Course of Action as a Prerequisite for the Cost Price Estimate of an Offensive Army Operation*, Vojno delo, 2014, Vol. 66, No. 4, pp. 148-162.

[61] BOŽANIĆ, D., SLAVKOVIĆ, R. & KAROVIĆ, S.: *Model of Fuzzy Logic Application to the Assessment of Riskin Overcoming the Obstacles during an Army Defensive Operation*, Vojno delo, 2015, Vol. 67, No. 4, pp. 240-260.

[62] BOŽANIĆ,D., TEŠIĆ,D., MARINKOVIĆ,D., MILIĆ,A. *Modeling of neuro-fuzzy system as a support indecision-making processes*, Reports

in Mechanical Engineering, 2021, Vol. 2, No. 1, pp. 222-234.

[63] MUHAMMAD,L.J., BADI,I., HARUNA,A.A., MOHAMMED,I.A.: *Selecting the Best Municipal Solid Waste Management Techniques in Nigeria Using Multi Criteria Decision Making Techniques*, Reports in Mechanical Engineering, 2021, Vol. 2, No. 1, pp. 180-189.

[64] DURMIĆ,E., STEVIĆ,Ž., CHATTERJEE,P., VASILJEVIĆ,M., TOMAŠEVIĆ,M.: *Sustainable supplier selection using combined FUCOM – Rough SAW model*, Reports in Mechanical Engineering, 2020, Vol. 1, No. 1, pp. 34-43.

[65] ISWAS,T.K., CHAKI,S., DAS,M.C.: *MCDM technique application to the selection of an Indian institute of technology*, Operational Research in Engineering Sciences: Theory and Applications, 2019, Vol. 2, No. 3, pp. 65-76.

[66] PAMUČAR,D., BOŽANIĆ,D., RANĐELOVIĆ,A.: *Multi-criteria decision making: An example of sensitivity analysis*, Serbian Journal of Management, 2017, Vol. 12, No. 1, pp. 1-27.

Received: 18.11.2021.
Accepted: 16.12.2021.

Primena hibridnog modela fuzzy AHP – VIKOR u izboru bespilotne letelice za potrebe taktičkih jedinica oružanih snaga

Bespilotne letelice predstavljaju neizostavan segment u paleti naoružanja kako vojnih tako i policijskih jedinica. Ekspanzija u razvoju bespilotnih letelica kako u komercijalne tako i u vojne svrhe stvorila je potrebu za konstantnim usavršavanjem dronova i protivdronskih sredstava. Širok spektar mogućnosti otvara im i širok dijapazon upotrebe. U radu je prikazan izbor bespilotne letelice, kao jednog značajnog borbenog sistema za potrebe taktičkih jedinica vojske i policije. Kompleksnost problema uslovljena je raznolikim taktičko – tehničkim I ekonomskim odlikama bespilotnih letelica, uslovila je upotrebu različitih metoda višekriterijumskog odlučivanja. Za izbor bespilotne letelice za potrebe taktičkih jedinica korišćen je hibridni model višekriterijumskog odlučivanja fuzzy AHP – VIKOR.

Definisani su kriterijumi od značaja za izbor bespilotne letelice za potrebe taktičkih jedinica, na osnovu kojih je izabrano najoptimalnije rešenje (bespilotna letelica). Kriterijumi su definisani na osnovu taktičko-tehničkih i ekonomskih odlika bespilotnih letelica. Proračun težinskih koeficijenata definisanih kriterijuma izvršen je primenom metode fuzzy AHP, dok je izbor drone bespilotne letelice (najpovoljnije alternative) na osnovu definisanih kriterijuma izvršen primenom metode VIKOR. Dobijeni rezultat predstavlja polaznu osnovu za nastavak istraživanja i implementaciju dronova bespilotnih letelica u taktičke jedinice vojske i policije.

Ključne reči: **bespilotne letelice, dron, Unmanned Combat Aircraft Vehicle (UCAV), fuzzy AHP, VIKOR, višekriterijumsko odlučivanje.**