Decision Making: Applications in Management and Engineering
Vol. 1, Number 1, 2018, pp. 51-66
ISSN: 2560-6018
DOI: https://doi.org/10.31181/dmame180151b

MULTI-CRITERIA DECISION-MAKING IN A DEFENSIVE OPERATION OF THE GUIDED ANTI-TANK MISSILE BATTERY: AN EXAMPLE OF THE HYBRID MODEL FUZZY AHP - MABAC

Dragan Bojanic[1]*, Mitar Kovač[2], Marina Bojanic[3] and Vladimir Ristic[4]

[1] Strategic Research Institute, University of Defense, Belgrade, Serbia
[2] University of Edukons, Faculty of Project and Innovation Management, Belgrade, Serbia
[3] Electrical Engineering School „Nikola Tesla", Pančevo, Serbia
[4] University of Defense, Military Academy, Belgrade, Serbia

Received: 3 January 2018;
Accepted: 31 January 2018;
Published: 15 March 2018.

Original scientific paper

Abstract: *The military decision-making process is a proven analytical process for designing operations, troops' movements, logistics or air defense planning. The hybrid FAHP-MABAC model is tested for obtaining/selecting the results for an optimal firing position of the guided anti-tank missile battery (GAMB).This study provides a multi-criteria decision-making (MCDM) model so that the confidence interval of fuzzy numbers describes the comparison in pairs whose degree is not determined before the comparison. By using mathematical expressions the confidence interval is brought into direct connection with the degree of certainty of decision-makers/expert of the comparison performed. In the group decision-making, the confidence intervals differ depending on the decision-maker/expert's opinion. Finally the sensitivity analysis is used to determine how sensitive a decision model is. The suggested model is expected to contribute to the development of the science of military-operations as well as to prove itself useful to the actors related to defense.*

Key Words: *Fuzzy AHP, MABAC, MCDM, Sensitivity Analysis.*

1. Introduction

MCDM is a systematic way of problem solving for any scientific research area. The military decision-making process is a proven analytical process for designing operations, troops' movements, logistics or air defense planning.

In most cases, the decision-making process in the military organization implies not having relevant information, which is characterized by a high degree of

* Corresponding author.
E-mail addresses: dragan.bojanic@mod.gov.rs (D. Bojanic), marbojanic@gmail.com (M. Bojanic), vladimir.ristic@mod.gov.rs (V. Ristic)

uncertainty, subjectivity and ambiguity. Generally, in the decision-making process for these problems, a large number of key and different criteria are involved. Therefore, it is advisable to use tools for their resolution such as MCDM processes that are nowadays widely used in the military (Kewley & Embrechts, 2002; De Leeneer & Pastijn, 2002; Zanjirani & Asgarib, 2007; Kose et al., 2013; Gyarmati, 2015; Goztepe & Kahraman, 2015; Andersson et al., 2015; Boccia et al., 2017), as well as in other research disciplines (Sánchez-Lozano et al., 2013). Fuzzy logic proves to be an appropriate tool (Sánchez-Lozano et al., 2015) to address the described uncertainties and ambiguities. In that way, fuzzy logic enables the exploitation of tolerance that exists in imprecision, ambiguity and partial truth of the results obtained through given research.

Anti-tank is defined as a combat against enemy's tanks and other armored equipment and vehicles. Its associated tasks include the closing of endangered directions, flanks, and junctions (Gordic et al., 2013). Anti-tank is a part of the combined combat arms directed against the tanks grouped for an attack or already directly attacking, as well as the armored equipment detached to their battle formation. For a successful combat, the organization of a solid anti-armor system is required, which includes anti-tank units as the basic element. The aim of anti-tank operations in a defensive operation is to prevent accidental penetration of the enemy's armored forces into our elements of combat disposition (Slavkovic et al., 2013; Jotić & Slavković,2016).

The new operational environment imposes the need to upgrade the defense science in the field of the preparation and conduct of combat operations (Knežević & Slavković, 2012). In the Serbian Army many decisions are made in the processes of planning, organization and preparation for the execution of missions and tasks. The useful tools which support the decision-making process are the methods of multi criteria decision-making.

The fundamental issue of multi-criteria group decision-making is finding procedures for choosing decisions that correspond to the desired solution, with the option of selecting and allocating the most acceptable alternative. The complexity of group decision-making is reflected in the fact that there are a number of criteria and alternatives with different levels of significance for the decision-makers/experts involved in decision-making.

This paper presents a hybrid model, using the fuzzificated Saaty's scale and the MABAC method (Multi-Attributive Border Approximation Area Comparison) (Božanić et al., 2015; Božanić et al., 2016a; Božanić et al., 2016b; Pamučar et al., 2016b). The paper is focused on the demonstration of a new way of fuzzification of the Saaty's scale used for comparison in pairs while varying a confidence interval depending on the comparison. The scale is used for obtaining criteria weight coefficients, while the MABAC method is used for the final ranking. This model is illustrated by an example of decision-making during the selection of firing position (POP) of the GAMB in the Army's defensive operation. The example presents only one segment from a series of decisions that decision-makers face in the preparation and execution of (military) operations. The sensitivity analysis is used to determine how sensitive a decision model is.

2. Description of the methods used in the hybrid AHP-MABAC model

The described MCDM model is based on the knowledge of several decision-making methods (areas), fuzzy logic, the AHP method (Saaty's scale) and the MABAC method. Fuzzy logic successfully covers vagueness and uncertainty that are often present in decision-supporting models. The Saaty's scale, which is an indispensable part of the AHP method, shows good results in defining the criteria weight coefficients, and it is increasingly applied with other methods (Knežević et al., 2015; Zhu et al., 1999). The MABAC method provides stable (consistent) solutions and it represents a reliable tool for rational decision-making (Pamučar & Ćirović, 2015).

3. Fuzzy logic and fuzzy sets

In fuzzy logic, an element's belonging to the specific set is not precisely defined - the element can be more or less part of the set; therefore, it is closer to human perception than conventional logic (Pamučar et al., 2016b). Fuzzy logic allows quantification of seemingly imprecise information, which is a very common situation when describing social phenomena. Fuzzy logic uses the experience of human expert in the form of linguistic if-then rules, while approximate reasoning mechanism uses managing action for the individual case. In this paper, approximate reasoning algorithm is used to display the influence of the entry criteria on decision preference in choosing the most appropriate firing GAMB position.

The first step in designing fuzzy sets is to define the degree of the membership of an element x (x∈X) in the set A. This is described with membership function μA (x), which in the classic theory has a value of 0 (does not belong) or 1 (belongs), while in a fuzzy set the membership function can have any value between 0 and 1. So, it can be said that the closer μA (x) is to 1, the greater belonging of x to A is, and *vice versa*. A fuzzy set A is defined as a set of ordered pairs

$$\mathrm{A}=\left\{\left(\mathrm{x},\mu_{\mathrm{A}}\left(\mathrm{x}\right)\right)\middle|\mathrm{x}\in\mathrm{X},0\le\mu_{\mathrm{A}}\left(\mathrm{x}\right)\le1\right\} \quad (1)$$

where:

- X is a universal set or a set of considerations based on which fuzzy set A is defined;
- μA (x) function of element x belonging to set A.

In this paper, triangular fuzzy numbers will be used. They will be presented in the form T = (t_1, t_2, t_3), where Fig. 1:

- t_2 is where the membership function of a fuzzy number has a value of 1;
- t_1 is the left distribution of the confidence interval of fuzzy number T, and,
- t_3 is the right distribution of the confidence interval of fuzzy number T.

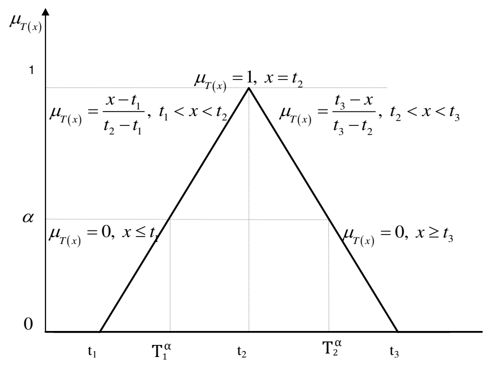

Figure 1. Triangular fuzzy number T (Pamučar et al., 2016a)

The membership function of fuzzy number T is defined in the following way:

$$\mu_{\tilde{T}}(x)=\begin{cases} 0, & x<t_1 \\ \dfrac{x-t_1}{t_2-t_1}, & t_1\le x\le t_2 \\ 1, & x=t_2 \\ \dfrac{t_3-x}{t_3-t_2}, & t_2\le x\le t_3 \\ 0, & x>t_3 \end{cases} \tag{2}$$

For its final purpose, fuzzy number T= (t_1, t_2, t_3) is converted into a real number.

4. Fuzzification of the Saaty's scale

One of the key phases in the application of this method is the development of the comparison matrix by pairs, corresponding to every level of the hierarchy. A pairwise comparison is performed according to the data collected by measuring them on the basis of beliefs, estimates or experiences of those who carry out the assessment (Čupić & Suknović 2010). The shown fuzzification of the Saaty's scale is presented in (Božanić et al., 2015; Božanić et al., 2016a; Božanić et al., 2016b; Pamučar et al., 2016b; Božanić, 2017).

The definition of this new fuzzificated Saaty's scale (Table 1) starts from the assumption that the decision-makers and analysts have a different degree of certainty γ_{ji}, concerning the accuracy of comparisons in pairs (Božanić et al., 2016a; Pamučar et al., 2016b). This degree of certainty differs from one comparative pair to another. The value of the degree of certainty belongs to interval $\gamma_{ji}\in[0,1]$. In the cases when $\gamma_{ji}=0$, it is considered that the decision-maker/analyst has no data about this relationship; hence it should not be used in the decision-making process because it points to absolute ignorance of the decision-making subject. The value of the degree of certainty where $\gamma_{ji}=1$ describes the absolute certainty of the decision-makers/analysts in the given comparison. The lower the certainty in the performed comparison is, the lower the element γ_{ji}.

Table 1. Fuzzified Saaty's scale for comparison in pairs (Božanić, 2017).

Definition	Standard value	Fuzzy number	Inverse values of the fuzzy number
Same importance	1	(1, 1, 1)	(1, 1, 1)
Low dominance	3	$\left(3\gamma_{ji},3,\left(2-\gamma_{ji}\right)3\right)$	$\left(1/\left(2-\gamma_{ji}\right)3,1/3,1/3\gamma_{ji}\right)$
High dominance	5	$\left(5\gamma_{ji},5,\left(2-\gamma_{ji}\right)5\right)$	$\left(1/\left(2-\gamma_{ji}\right)5,1/5,1/5\gamma_{ji}\right)$
Very high dominance	7	$\left(7\gamma_{ji},7,\left(2-\gamma_{ji}\right)7\right)$	$\left(1/(2-\gamma_{ji})7,1/7,1/7\gamma_{ji}\right)$
Absolute dominance	9	$\left(9\gamma_{ji},9,\left(2-\gamma_{ji}\right)9\right)$	$\left(1/(2-\gamma_{ji})9,1/9,1/9\gamma_{ji}\right)$

Intermediate values	2, 4, 6, 8	$\left(x\gamma_{ji}, x, \left(2-\gamma_{ji}\right)x\right)$ $x = 2,\ 4,\ 6,\ 8$	$\left(1/\left(2-\gamma_{ji}\right)x, 1/x, 1/x\gamma_{ji}\right)$ *x = 2, 4, 6, 8*

By defining different values of parameter γ_{ji}, the left and the right distribution of fuzzy numbers change from one comparison to another, according to the expression:

$$T=\left(t_1,t_2,t_3\right)=\begin{cases} t_1=\gamma t_2, & t_1\le t_2, \quad t_1,t_2\in\left[1/9,9\right] \\ t_2=t_2, & t_2\in\left[1/9,9\right] \\ t_3=\left(2-\gamma\right)t_2, & t_3\le t_2, \quad t_2,t_3\in\left[1/9,9\right] \end{cases} \tag{3}$$

the value of t_2 represents the value of linguistic expressions from the classic Saaty's scale, which in a fuzzy number has a maximum membership $t_2 = 1$

Fuzzy number $T=\left(t_1,t_2,t_3\right)=\left(x\gamma,x,\left(2-\gamma\right)x\right),\quad x\in\left[1,9\right]$ is defined by the expressions:

$$t_1=x\gamma=\begin{cases} x\gamma, & \forall\ 1\le x\gamma\le x \\ 1, & \forall\ x\gamma<1 \end{cases} \tag{4}$$

$$t_2=x,\ \forall\ x\in\left[1,9\right] \tag{5}$$

$$t_3=\left(2-\gamma\right)x,\forall x\in\left[1,9\right] \tag{6}$$

Inverse fuzzy number $T=\left(t_1,t_2,t_3\right)=\left(x\gamma,x,\left(2-\gamma\right)x\right),\quad x\in\left[1,9\right]$ is defined as follows:

$$1/t_3=1/\left(2-\gamma\right)x=\begin{cases} 1/\left(2-\gamma\right)x, & \forall\ 1/\left(2-\gamma\right)x<1 \\ 1, & \forall\ 1/\left(2-\gamma\right)x\ge 1 \end{cases},x\in\left[1,9\right] \tag{7}$$

$$1/t_2=1/x,\ \forall\ 1/x\in\left[1,9\right] \tag{8}$$

$$1/t_1=1/\gamma x,\forall 1/x\in\left[1,9\right] \tag{9}$$

The defined scale is further used in standard steps of the AHP method, which is described in a number of papers (Čupić & Suknović2010), (Inđić et al., 2014) and others.

Based on the pre-defined scale, the decision-makers and analysts fill in the new, modified matrix:

$$A=\begin{matrix} & C_1 & C_2 & \cdots & C_n \\ C_1 & a_{11};\gamma_{11} & a_{12};\gamma_{12} & \cdots & a_{1n};\gamma_{1n} \\ C_2 & a_{21};\gamma_{21} & a_{22};\gamma_{22} & \cdots & a_{2n};\gamma_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C_n & a_{n1};\gamma_{n1} & a_{n2};\gamma_{n2} & \cdots & a_{nn};\gamma_{nn} \end{matrix} \tag{10}$$

As can be seen, the matrix is extended with the degree of certainty in the comparison made, whereby $\gamma_{ji}=\gamma_{ij}$, where $\gamma_{ji}\in[0,1]$. After the calculation is finished, the defuzzification can be performed using one of well-known methods. Some of the well-known expressions for defuzzification (Seiford, 1996) are the following ones:

$$\text{defazzy S}=\left[\left(t_3-t_1\right)+\left(t_2-t_1\right)\right]3^{-1}+t_1 \qquad (11)$$

$$\text{defazzy S}=\left[\lambda t_3+t_2+\left(1-\lambda\right)t_1\right]2^{-1} \qquad (12)$$

Where λ represents the degree of optimism.

The defined scale is also suitable for group decision-making, which is nowadays becoming more and more popular. Involving experts greatly improves the quality of decisions made because knowledge and experience are collected and consolidated into a single unit.

5. MABAC method

The MABAC method was developed by Pamučar and Ćirović (Pamučar & Ćirović, 2015). The basic setting of the MABAC method is reflected in the definition of the distance of the criterion function of each of the observed alternatives from the approximate border area. The text that follows shows the procedure of implementation of the MABAC method in six steps, its mathematical formulation being:

Step 1. Creation of initial decision matrix (X). In the first step, the evaluation of m alternatives by n criteria is carried out. The alternatives are presented with vectors $A_i = (x_{i1}, x_{i2}, \ldots x_{in})$, where x_{ij} is the value of alternative i according to criteria j $(i = 1,2,\ldots, m; j = 1,2,\ldots, n)$.

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \ldots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{11} & x_{22} & & x_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ x_{1m} & x_{2m} & \ldots & x_{mn} \end{bmatrix} \end{array} \qquad (13)$$

where m indicates the number of alternatives, and n indicates the total number of criteria.

Step 2. Normalization of initial matrix (X) elements.

$$N = \begin{array}{c} \\ A_1 \\ A_2 \\ \ldots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots & C_n \end{array} \\ \begin{bmatrix} t_{11} & t_{12} & \ldots & t_{1n} \\ t_{11} & t_{22} & & t_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ t_{1m} & t_{2m} & \ldots & t_{mn} \end{bmatrix} \end{array} \qquad (14)$$

The elements of normalized matrix (N) are obtained using the following expressions:

a) For the "benefit" type criteria

$$t_{ij} = \frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \qquad (15)$$

b) For the "cost" type criteria

$$t_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \tag{16}$$

where x_{ij}, $x_i^+$and x_i^- are the components of initial decision matrix (X), where x_i^+ and x_i^- are defined as:

x_i^+= max (x_1, x_2,..., x_m) and represents the maximum value of the observed criteria by alternatives,

x_i^+= min(x_1, x_2,..., x_m) and represents the minimum value of the observed criteria by alternatives.

Step 3. Calculation of weighted matrix elements (V). The elements of weighted matrix (V) are calculated on the basis of expression (17):

$$v_{ij} = w_i \bullet t_{ij} + w_i \tag{17}$$

where t_{ij} are the elements of normalized matrix (N), and w represents the weight coefficient of criteria. By applying expression (17), we get weighted matrix V that otherwise can be written as:

$$V = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix} = \begin{bmatrix} w_1 \bullet t_{11} + w_1 & w_2 \bullet t_{12} + w_2 & \cdots & w_n \bullet t_{1n} + w_n \\ w_1 \bullet t_{21} + w_1 & w_2 \bullet t_{22} + w_2 & \cdots & w_n \bullet t_{2n} + w_n \\ \cdots & \cdots & \cdots & \cdots \\ w_1 \bullet t_{m1} + w_1 & w_2 \bullet t_{m2} + w_2 & \cdots & w_n \bullet t_{mn} + w_n \end{bmatrix} \tag{18}$$

where n is the total number of criteria, and m is the total number of alternatives.

Step 4. Determination of approximate border area (G) matrix. The border approximate area (BAA) for each criterion is determined by expression (19)

$$g_i = \left(\prod_{j=1}^{m} v_{ij} \right)^{1/m} \tag{19}$$

where v_{ij} are weighted matrix elements (V) and m represents the total number of alternatives.

After determining value g_i according to the criteria, we form the matrix of approximate border areas G (20) size nx1 (n is the total number of criteria by which the election of the offered alternatives is made).

$$\begin{matrix} & C_1 & C_2 & \cdots & C_n \\ G = & [g_1 & g_2 & \cdots & g_n] \end{matrix} \tag{20}$$

Step 5. Calculation of the matrix elements distance from border approximate area (*Q*)

$$Q = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1n} \\ q_{21} & q_{22} & & q_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ q_{m1} & q_{m2} & \cdots & q_{mn} \end{bmatrix} \tag{21}$$

The distance of the alternatives from border approximate area (q_{ij}) is defined as the difference between weighted matrix elements (V) and the values of border approximate areas (G).

$$Q = V - G \tag{22}$$

which otherwise can be written as:

$$Q = \begin{bmatrix} v_{11} - g_1 & v_{12} - g_2 & \cdots & v_{1n} - g_n \\ v_{21} - g_1 & v_{22} - g_2 & \cdots & v_{2n} - g_n \\ \cdots & \cdots & \cdots & \cdots \\ v_{m1} - g_1 & v_{m2} - g_2 & \cdots & v_{mn} - g_n \end{bmatrix} \tag{23}$$

where g_i represents the border approximate area for criterion C_i, $v_{ij.}$ is weighted matrix elements (V), n represents the number of criteria, and m represents the number of alternatives.

Alternative A_i may belong to border approximate area (G), upper approximate area (G^+) or lower approximate area (G^-), respectively $A_i \in \{G^- \vee G^+ V\ G^-\}$. Upper approximate area (G^+) is an area in which the ideal alternative is found (A^+), while lower approximate area (G^-) is an area in which the anti-ideal alternative (A^-) is found (Fig. 2).

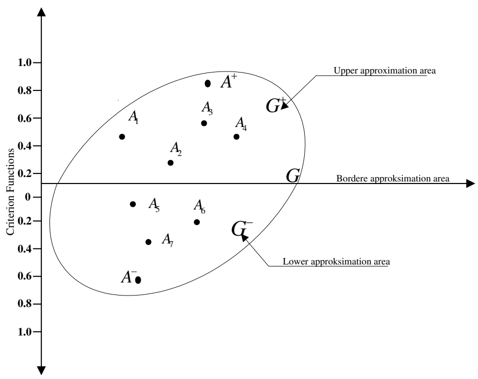

Figure 2. Presentation of upper (G^+), lower *(G^-)* and border *(G)* approximation areas (Pamučar, Ćirović, 2015)

Belonging of alternative A_i to approximate area *(G ,*G^+ or G^-) is determined on the basis of expression (24)

$$A_i \in \begin{cases} G^+ \text{ if } q_{ij} > 0 \\ G \text{ if } q_{ij} = 0 \\ G^- \text{ if } q_{ij} < 0 \end{cases} \tag{24}$$

In order for alternative *At* to be chosen as the best from the set, it is necessary that, according to as many criteria as possible, it belongs to upper approximate area (G^+).

Step 6. Ranking alternatives. Calculation of the criteria function values by alternatives is obtained as the sum of the distances of the alternatives from border approximate areas (q_i). Summing the elements of matrix Q by rows gives the final values of the criteria function alternatives

$$S_i = \sum_{j=1}^{n} q_{ij}, \; j = 1,2,...,n, \; i = 1,2,...,m \tag{25}$$

where n represents the number of criteria, and m represents the number of alternatives.

6. Selection of the optimal firing position of the Guided anti-tank missile battery in a defense operation

6.1. Identification of the criteria and calculation of the weight coefficients of the criteria

A guided anti-tank missile battery performs its tasks from the firing position (POP). It is composed of self-propelled launchers LRSPM83. The (POP) is a part of the land in the area of the operation, prepared and occupied or intended to be occupied by the artillery units for the execution of firing support (The military lexicon, 1981).

"In order to ensure the effectiveness of fire control and fire coordination, the distance in length is 100–300m between self-propelled launchers, and 300–400m between platoons. The dimensions of deployment areas can extend to 1,4-2 km in width and 1 km in length for batteries, 1km in width and 500m in length for platoons depending on the combat situation, terrain, and the number of assets involved." (Fig. 3) (Rule book self-propelled anti-tank battery – platoon, 2016).

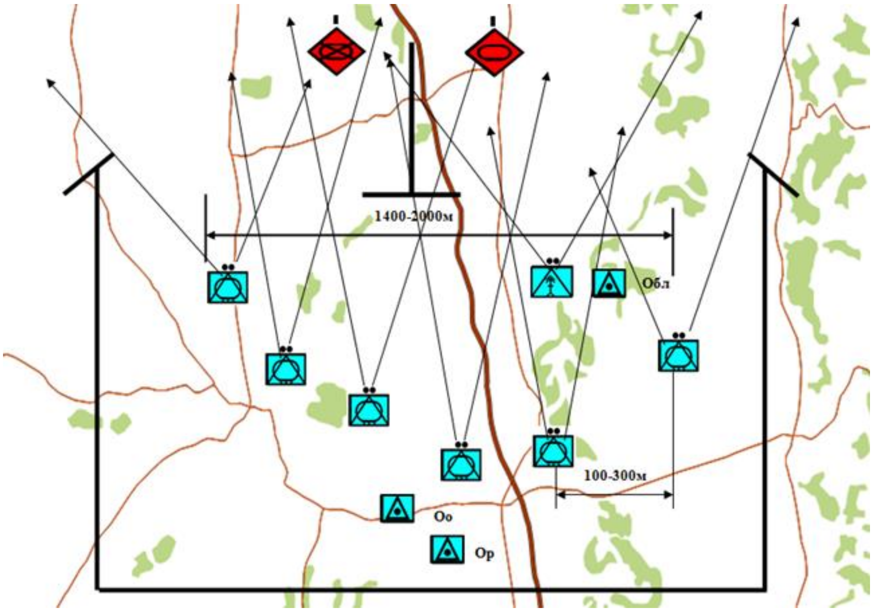

Figure 3. Battery deployment on POP

Decision-makers usually have to select an (POP) area relying on the acquired theoretical knowledge, experience and assessment in the specific situation. A number of criteria that influence the ranking and selection of alternatives indicate a possibility of applying multiple criteria methods. Founded on the available literature, the ranking criteria that are the basis for selection-making are also defined:

C_1– „distance to the targets area"- the distance at which the guided armor-piercing missiles will neutralize the enemy armored vehicle in the direction of the attack. The range of guided armor-piercing missiles is determined by their maximum launching distance and the distance of the fire line – influenced by the terrain in front of their firing positions;

C_2– „speed of occupancy POP" - represents the estimate of time for which launching devices from the expected region will make an arrival at POP;

C_3– „maneuver capability " -the maneuver capability of guided anti-tank missile units is determined by their mobility (movements to firing positions, during maneuvers to deployment areas), and the time required for occupation and leaving of the deployment areas;

C_4 – „fortification conditions" - terrain features that allow successful fortification of artillery to enhance force protection;

C_5 – „quality of access roads" - road characteristics that appreciate the possibility of fast and successful settling and abandonment of POP;

C_6 – „masking conditions " - terrain features that enable successful masking of GAMB and movement of GAMB of parts as well as masking of the effects of the rocket launching.

The values of criteria C_1 and C_2 are described numerically and the values of criteria C_3, C_4, C_5i C_6 are described with fuzzy linguistic descriptors, Fig. 4 (very poor - VL, poor - L, medium - S, good - D and great - O).

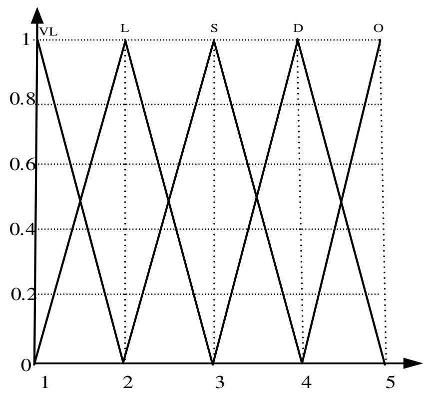

Figure 4. Graphic display of fuzzy linguistic descriptors (Božanić et al., 2016b; Pamučar et al., 2016b; Božanić, 2017)

The first step in defining the weight coefficients is to define the square comparison matrix. Two elements of the hierarchy (models) are compared using the Saaty's classic scale and by defining the degree of certainty of a given claim according to expression (10). The degree of inconsistency of the given matrix is 0.0352.

Table 2. Comparison matrix in pairs

Crit.	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1;1	1.4;0.7	1.2;0.6	4.5;0.9	2.5;0.9	3.1;0.9
C_2	0.7;07	1;1	1.1;0.1	1.3;0.9	1.8;0.6	2.6;0.4

C_3	0.8;0.6	0.9;0.1	1;1	2.0;0.5	2.0;0.7	4.1;0.9
C_4	0.2;0.9	0.8;0.9	0.5;0.5	1;1	2.4;0.5	2.5;0.9
C_5	0.4;0.9	0.5;0.6	0.5;0.7	0.4;0.5	1;1	1.2;0.5
C_6	0.3;0.9	0.4;0.4	0.2;0.9	0.4;0.9	0.8;0.5	1;1

The values of the Table 2 matrix are converted into fuzzy numbers by applying the fuzzificated Saaty's scale (Table 1), so that a new matrix is shown in Table 3.

Table 3. Comparison matrix in pairs after fuzzification

Crit.	C1	C2	C3	C4	C5	C6
C1	1;1;1	1.0;1.4;1.8	1.0;1.3;1.8	4.1;4.5;4.9	2.3;2.5;2.8	2.8;3.1;3.4
C2	0.6;0.7;1.0	1;1;1	1.0;1.1;2.1	1.2;1.3;1.4	1.1;1.9;2.6	1.0;2.6;4.2
C3	0.6;0.8;1.0	0.5;0.9;1.0	1;1;1	1.0;2.0;3.0	1.4;2.0;2.6	3.7;4.1;4.5
C4	0.2;0.2;0.2	0.7;0.8;0.8	0.3;0.5;1.0	1;1;1	1.2;2.4;3.7	2.3;2.5;2.8
C5	0.4;0.4;0.4	0.4;0.5;0.9	0.4;0.5;0.7	0.3;0.4;0.8	1;1;1	1.0;1.2;1.8
C6	0.3;0.3;0.4	0.2;0.4;0.9	0.2;0.2;0.3	0.4;0.4;0.4	0.5;0.8;1.0	1;1;1

The weight vector w of every criterion of the Table 3 matrix is the sum of the linguistic expressions that describe the criteria in the same row of the Table 3 matrix, which is divided by the sum of all linguistic expressions that describe the criteria of the Table 3 matrix. After the calculation, the weight vectors of the criteria are obtained (Table 4). The label "l" represents the left distribution of the fuzzy number; "d" represents the right distribution of the fuzzy number and "s" - a place where the level of the membership of the fuzzy number has a value one.

Table 4. Fuzzy weight vectors of the criteria

Criteria	"l"	"s"	"d"
C_1	0.203	0.293	0.424
C_2	0.113	0.191	0.339
C_3	0.126	0.217	0.327
C_4	0.085	0.139	0.234
C_5	0.059	0.092	0.159
C_6	0.045	0.068	0.119

Finally, by applying expression (11) the defuzzification of the weight coefficients of the evaluation criteria is performed. The final values of the weight coefficients of the criteria are given in Table 5.

Table 5. Final values of the weight coefficients

Criteria	Weight coefficients (w)
C_1	0.307
C_2	0.214
C_3	0.223
C_4	0.152
C_5	0.103
C_6	0.077

6.2. Application of the MABAC method for ranking alternatives

In order to apply the MABAC method, six alternatives have been selected (from A_1 to A_6) (Table 6). The alternatives represent a land area that the artillery means will be deployed on. The initial decision matrix is presented in Table 6. Since evaluation criteria C_3, C_4, C_5 and C_6 have a qualitative character, for the evaluation of alternatives by criteria, the fuzzy linguistic descriptors scale is used.

Table 6. Initial decision matrix

Alternative	C_1 (min)	C_2 (min)	C_3 (max)	C_4 (max)	C_5 (max)	C_6 (max)
A_1	1300	6.00	S	o	d	s
A_2	2200	8.00	O	vl	s	o
A_3	1950	11.00	L	s	l	s
A_4	1400	10.00	Vl	l	s	o
A_5	2500	5.00	S	vl	l	s
A_6	1700	9.00	O	d	d	l

Defuzzification is performed by applying expression (12). The next step is the normalization of the matrix elements and the final values of the normalized matrix are presented in Table 7.

Table 7. Normalized matrix

Alternative	C1 (min)	C2 (min)	C3 (max)	C4 (max)	C5 (max)	C6 (max)
A_1	1.000	0.833	0.500	1.000	1.000	0.375
A_2	0.250	0.500	1.000	0.000	0.500	1.000
A_3	0.458	0.000	0.201	0.500	0.000	0.375
A_4	0.917	0.167	0.000	0.201	0.500	1.000
A_5	0.000	1.000	0.500	0.000	0.000	0.375
A_6	0.667	0.333	1.000	0.799	1.000	0.000

Using the next steps of the MABAC method, the distance values of the alternatives from the border approximate area are obtained and their ranking is shown in Table 8.

Table 8. Ranking of the alternatives

Alternative	Si	Rang
A_1	0.309	1
A_2	0.055	3
A_3	-0.200	6
A_4	0.032	4
A_5	-0.119	5
A_6	0.229	2

Based on the obtained distances from the ideal alternative, it can be concluded that alternative (A_1) is the most appropriate alternative while alternative (A_3) is the least favorable one.

7. Sensitivity analysis of the output results

It is recommended as a means of checking the stability of the results against the subjectivity of decision-makers. The sensitivity analysis of the results is carried out by changing the initial weight coefficients of the evaluation criteria. Table 9 gives the scenarios of change of weight coefficients (seven scenarios), based on which the ranking of the already presented alternatives is performed.

Table 9. Scenarios with different weights of the criteria

Criteria	S_1	S_2	S_3	S_4	S_5	S_6	S_7
C_1	0.2	0.6	0.1	0.1	0.1	0.1	0.1
C_2	0.2	0.1	0.6	0.1	0.1	0.1	0.1
C_3	0.2	0.1	0.1	0.6	0.1	0.1	0.1
C_4	0.2	0.1	0.1	0.1	0.6	0.1	0.1
C_5	0.2	0.1	0.1	0.1	0.1	0.6	0.1
C_6	0.2	0.1	0.1	0.1	0.1	0.1	0.6

The ranking of the alternatives after the application of the scenario is given in Table 10. By analyzing the obtained results, it can be concluded that there is significant stability of the output results in most of the scenarios. This is supported by the fact that A1 and A4 are most often ranked as the first or the second, which is expected for a stable system.

Table 10. Ranks of alternatives by applying different situations

Alternative	Rank from Table 8	S_1	S_2	S_3	S_4	S_5	S_6	S_7
A_1	1	1	1	1	3	1	1	3
A_2	3	3	4	3	2	5	3	1
A_3	6	6	5	6	6	3	6	6
A_4	4	4	2	5	5	4	2	2
A_5	5	5	6	2	4	6	5	5
A_6	2	2	3	4	1	2	4	4

8. Conclusions

The application of the (MCDM) model is successfully presented in the paper while the sensitivity analysis indicates the potential of the application of the created models to support decision-making during the planning process of the Land Forces operation. In a similar way, the application would be conducted in group decision-making.

A practical example of the fuzzy scale demonstrated a possibility of using the hybrid fuzzy AHP-MABAC model, its performance in ranking the offered alternatives. The analysis of the output results sensitivity has shown that the hybrid FAHP-MABAC model provides stable solutions for the problem of choosing an optimal firing position of the Guided anti-tank missile battery. The proposed hybrid approach can solve not only the problems of location choice, but also many other decision-making ones.

From all of the above mentioned, it can be concluded that the fuzzificated Saaty's scale improves decision-making by taking into account the degree of certainty of decision-makers in the shown pairwise comparison.

References

***(1981). The military lexicon (Only in Serbian: Vojni leksikon). Belgrade: Military publishing institute/Vojnoizdavački zavod.

***(2016). Rule book self-propelled anti-tank battery – platoon (Only in Serbian: Pravilo samohodna protivoklopna baterija-vod). Belgrade: GŠVS.

Andersson, K., Bang M., Marcus, C., Persson, B., Sturesson, P., Jensen, E., & Hult, G. (2015). Military utility: A proposed concept to support decision-making. Technology in Society Volume, 43, 23-32.

Boccia, M, Verde, P., Angelino, G., Carrozzo, P., Vecchi, D., Piccardi, P., Colangeli, S., Cordellieri, P., Ferlazzo, F., & Giannini, A. (2017). Effect of professional expertise and exposure to everyday life decision-making on moral choices. Neuroscience Letters Volume, 654, 80-85.

Bojanić, D., Bojanić, M., & Ristić, V. (2017). Application of hybrid model fuzzy AHP – MABAC in ranking the potential locations of the firing position of anti-armour battery in defense operation. Proceedings of The 1st International Conference on Management, Engineering and Environment (ICMNEE) (pp. 395-407). Belgrade: ECOR (RABEK).

Božanić, D. (2017). The model of decision support in for river crossing in the attack operation of the Land Army (Only in Serbian: Model podrške odlučivanju pri savlađivanju vodenih prepreka u napadnoj operaciji Kopnene vojske). Doctoral dissertation, Military Academy, University of Defence, Belgrade, Serbia.

Božanić, D., Karović, S., & Pamučar, D. (2015). The fuzzification of Saaty's scale using a triangular fuzzy number with a variable confidence interval (Only in Serbian: Fazifikacija Saaty-jeve skale primenom trouglastog fuzzy broja sa promenljivim intervalom poverenja). In Mladenović, N., Urošević, D., & Stanimirovć, Z., Proceedings of The Symposium on Operational Research (pp. 420-424). Srebrno jezero: The SANU Mathematical Institute.

Božanić, D., Pamučar, D., & Karović , S. (2016a). Use of the fuzzy AHP – MABAC hybrid model in ranking potential locations for preparing laying-up positions. Vojnotehnički glasnik/Military Technical Courier, 64(3), 705-729.

Božanić, D., Pamučar, D., & Karović, S. (2016b). Application the MABAC method in support of decision-making on the use of force in a defensive operation. Tehnika, 71(1), 129-137.

Čupić, M., & Suknović, M. (2010). Decision making (Only in Serbian: Odlučivanje). Belgrade: Faculty of Organisational Sciences.

De Leeneer, I., & Pastijn, H. (2002). Selecting land mine detection strategies by means of outranking MCDM techniques. European Journal of Operational Research, 139(2), 327-338.

Gordic, M., Slavkovic, R., & Talijan, M. (2013). A conceptual model of the state security system using the modal experiment. Carol I" National Defence University Publishing House, 48(3), 58-67.

Göztepe, K., & Kahraman C. (2015). A New Approach to Military Decision Making Process: Suggestions from MCDM Point of View. Proceedings of The International Conference on Military and Security Studies, 118-122.

Gyarmati, J. (2015). Military Application of Multi-Criteria Decision Making. AARMS 14(4), 291–297.

Inđić, D., Luković, Z., & Mučibabić, S. (2014). Engagement model for NBC service units during chemical accidents, Vojnotehnički glasnik/Military Technical Courier, 62(1), 23-41.

Jotić, S., & Slavković, R. (2016). Artillery and rocket support in operations, Vojno delo, 68(7), 278-294.

Kewley, H. R., & Embrechts, J. M. (2002). Computational military tactical planning system. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 32(2), 161-171.

Knežević, N., Macura, D., & Bojović, N. (2015), Application of the A'WOT method for the selection of postal services development scenario in the Republic of Serbia. Tehnika, 70(1), 158-163.

Knežević, Z., & Slavković, R. (2012). Characteristics and problems of artillery-rocket support forces use in combat operations, Vojno delo, 64(4), 115-128.

Kose E., Kabak M., & Aplak H. (2013). Grey theory based MCDM procedure for sniper selection problem. Grey Systems: Theory and Application, 3(1), 35-45.

Pamučar, D., & Ćirović, G. (2015). The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC). Expert Systems with Applications, 42(6), 3016-3028.

Pamučar, D., Božanić, D., & Milić, A. (2016a). Selection of a course of action by Obstacle Employment Group based on a fuzzy logic system. Yugoslav journal of operations research, 26(1), 75-90.

Pamučar, D., Božanić, D., Kurtov, D. (2016b). 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, 64(4), 966-986.

Sánchez-Lozano, J. M., Serna J., & Dolón-Payán, A. (2015). Evaluating military training aircrafts through the combination of multi-criteria decision making processes with fuzzy logic. A case study in the Spanish Air Force Academy Aerospace Science and Technology, 42, 58-65.

Sánchez-Lozano, J. M., Teruel-Solano, J., Soto-Elvira P. L., & García-Cascales M. S. (2013). Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) Methods for the evaluation of solar farms locations: case study in south-eastern Spain. Renew. Sustain. Energy Rev., 24, 544–556.

Seiford, L.M. (1996). The evolution of the state-of-art (1978-1995). Journal of Productivity Analysis, 7, 99-137.

Slavkovic, R., Talijan, M., & Jelic, M. (2013). Relationship between theory and doctrine of operational art. Security and Defence Quarterly, 1(1), 54-75.

Zanjirani, R., & Asgarib, F. N. (2007). Combination of MCDM and covering techniques in a hierarchical model for facility location: A case study. European Journal of Operational Research, 176(3), 1839-1858.

Zhu, K.J., Jing, Y., & Chang, D.Y. (1999). A discussion on extent analysis method and applications on fuzzy AHP. European Journal of Operational Research, 116(18), 450-456.