APPLICATION OF AHP AND MABAC METHODS IN CHOOSING A COMBINED CONSTRUCTION MACHINE FOR FLOOD PREVENTION AND EARTHQUAKE REMEDIATION

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Abstract: *This paper presents the selection of the optimal combined construction machine - an alternative for flood prevention and earthquake remediation using the AHP-MABAC hybrid model. The AHP method was used to obtain the weighting coefficients of the criteria, and the MABAC method was used for analysis when choosing the best alternative. After completing this analysis, the alternatives are ranked from best to worst option. Based on the obtained rank, a decision is made to choose the best alternative, thereby increasing the efficiency in protecting and rescuing people, livestock and material goods affected by floods and earthquakes. In the conclusion, an overview is given of the importance and possibilities of applying AHP and MABAC methods when choosing the best alternative.*

Key words: *emergency situations, decision-making, AHP, MABAC*

1. INTRODUCTION

Over the past years, Serbia has faced numerous disasters that have led to significant human casualties and enormous material damage, where natural disasters undermine the safety and survival of entire cities. Natural disasters take many human lives every day and destroy and degrade the environment in various ways, causing great material damage and losses. Natural disasters such as floods, earthquakes, droughts, fires, escarpments, and landslides are becoming more frequent. Therefore, the general goals that the social community strives for are an adequate response to such disasters and an increase in safety. In order to achieve this, to a certain extent, quick decision-making is necessary.

As a result of industrialization and development of the economy, large pollutions have occurred over time, which have left an indelible mark on nature. As one of the consequences, there are climate changes that have greatly influenced the increase in the number of natural disasters and their intensity, and thus the consequences. A natural disaster is an elemental calamity whose consequences threaten the safety, life, and health of many people, material and cultural goods or the environment on a larger scale, and the occurrence or consequences of which cannot be prevented or eliminated by the regular action of competent authorities and services (Law on Reducing the Risk of disaster and emergency management, 2018).

The Balkans is an area prone to seismic activity and floods. Almost every year there are floods due to the appearance of torrential rivers due to a large amount of precipitation, which cause great damage to households and agriculture, and overflowing of large rivers is not rare either. On the other hand, we also witness of many earthquakes. In this context, preparations for defence against floods and for eliminating the consequences of earthquakes should represent a continuous process that serves the purpose of improving the entire system of protection and rescue.

The goal of this work is to create a model for decision support, by which the choice of a combined construction machine is made, which would be used in certain segments for flood prevention and remediation of consequences in the event of an earthquake. By applying the model, it would be significantly easier for decision makers to choose one type of combined construction machine from a set that includes a large number of these machines from different manufacturers.

In addition to the introduction, the work has three other units. The second part describes the methods that are applied. The third part includes a case study, while the last part contains the conclusion of the work.

2. DESCRIPTION OF METHODS

Decision-making represents the choice of one among an unlimited number of possibilities (Mora, 1980, cited in Cupic and Suknovic, 2010). In essence, decision-making is a process in which one is selected from a set of numerous possibilities, that is, alternatives based on certain criteria (Cupic M, Suknovic M, 2010). The persons who make the choice of alternatives are called decision makers (DM). To this day, many different decision-making methods have been developed, based on different mathematical models, which solve problems, that is, make decisions. In this paper, the AHP-MABAC hybrid model was used, where the AHP - Analytical Hierarchical Process method was used to determine the weighting coefficients of the criteria, and the MABAC (Multi-Attributive Border Approximation area Comparison) method was used to rank the alternatives.

2.1. AHP method

The AHP method was developed by Tomas Saaty (1980) and is one of the most famous and most frequently used methods in solving problems in the field of strategic management, finance, equipment selection, etc. It serves as an aid to DMs in solving complex decision-making problems involving many DMs. AHP is a multi-criteria technique based on decomposing a complex problem into a hierarchy. The goal is at the top of the hierarchy, while the criteria, sub-criteria and alternatives are at the levels and sub-levels of the hierarchy (Pamucar, 2018; Pamucar et al., 2016; Pamucar et al., 2011).

Apart from the hierarchical structuring of the problem, AHP differs methodologically from other multi-criteria methods in that it performs a comparison in pairs of elements at a given level of the hierarchy in relation to elements at a higher level. The comparison of pairs of elements is done based on Saaty's rating scale (Table 1).

Table 1. Saaty's rating scale

IMPORTANCE	DEFINITION	EXPLANATION
1	of the same importance	The two elements are of identical importance in relation to the goal
3	low dominance	Experience or judgment slightly favors one element over another
5	high dominance	Experience or judgment strongly favors one element over the other
7	demonstrated dominance	The dominance of one element confirmed in practice
9	absolute dominance	Dominance of the highest degree
2, 4, 6, 8	intermediate values	Compromise or further division required

The corresponding hierarchical structure of the problem of comparing each criterion with each other can be represented by the following evaluation matrix:

Table 2. Assessment matrix in pairs of criteria

Criteria	c_1	c_2	c_3	...	c_n
c_1	-	p_{12}	p_{13}	...	p_{1n}
c_2		-	(p_{23})	...	p_{2n}
c_3			-	...	p_{3n}
...				-	...
c_n					-

The values on the main diagonal are not shown, because the criteria are not compared with themselves, while the values in brackets represent the inverted ratio of preferences, so that (p_{23}) at the intersection of c_2 and c_3 has a real value in the following matrix $1/p_{23}$. An approximate procedure consisting of the following steps is used to obtain the vector of weight coefficients of the criteria (Pamucar D, 2017):

Step 1: Rework the matrix of pairwise comparisons;

Step 2: Calculate the sum of the elements in each column of the processed matrix;

Step 3: Divide each element of the column by the sum of the values of that column;

Step 4: Calculate the sum of the elements in each row and then determine the mean value of each row.

The values obtained in this way represent the weighting coefficients of the criteria.

Finally, a special procedure is used to check the consistency degree of the initial decision-making matrix. The maximum permissible deviation from the ideal comparison is 10%.

2.2. MABAC method

The MABAC method is a more recent method developed by Pamucar and Cirovic (2015). The basic setting of the MABAC method is reflected in the definition of the distance of the criterion function of each observed alternative from the boundary approximate area (BAA). In the following part, the procedure for implementing the MABAC method is presented, which consists of 6 steps (Pamucar, 2018, Bozanic et al., 2016):

Step 1. Formation of the initial decision matrix (*X*). In the first step, *m* alternatives are evaluated according to *n* criteria. Alternatives are represented by vectors $A_i = (x_{i1}, x_{i2}, ..., x_{in})$, where x_{ij} is the value of the *i*th alternative according to the *j*th criterion (i=1,2,...,m; j=1,2,..,n).

$$X = \begin{array}{c} A_1 \\ A_2 \\ \dots \\ A_m \end{array} \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{12} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{1m} & x_{2m} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

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

Step 2. Normalization of the initial matrix elements (*N*).

$$N = \begin{array}{c} A_1 \\ A_2 \\ \dots \\ A_m \end{array} \begin{bmatrix} t_{11} & t_{12} & \dots & t_{1n} \\ t_{12} & t_{22} & \dots & t_{2n} \\ \dots & \dots & \dots & \dots \\ t_{1m} & t_{2m} & \dots & t_{mn} \end{bmatrix} \quad (2)$$

The elements of the normalized matrix (*N*) are obtained by applying the expression:

a) for criteria of the "benefit" type (the higher the value of the criteria, the more desirable):

$$t_{ij} = \frac{x_{ij} - xi^-}{x_i^+ - x_i^-} \quad (3)$$

b) for criteria of the "cost" type (smaller criteria value is preferable):

$$t_{ij} = \frac{x_{ij} - xi^+}{x_i^- - x_i^+} \quad (4)$$

where x_{ij}, x_i^+ и x_i^- represent the elements of the initial decision matrix (*X*), where x_i^+ and x_i^- are defined as:

$x_i^+ = \max(x_1, x_2, \dots, x_m)$ and represents the maximum values of the observed criterion by alternatives.

$x_i^- = \min(x_1, x_2, \dots, x_m)$ and represents the minimum values of the observed criterion by alternatives.

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

$$v_{ij} = w_i * t_{ij} + w_i \quad (5)$$

where t_{ij} represent the elements of the normalized matrix (*N*), w_i represent the weighting coefficients of the criteria. Applying expression (5), we get the weighted matrix *V*:

$$V = \begin{bmatrix} w_1 * t_{11} + w_1 & w_2 * t_{12} + w_2 & \dots & w_n * t_{1n} + w_n \\ w_1 * t_{21} + w_1 & w_2 * t_{22} + w_2 & \dots & w_n * t_{2n} + w_n \\ \dots & \dots & \dots & \dots \\ w_1 * t_{m1} + w_1 & w_2 * t_{m2} + w_2 & \dots & w_n * t_{mn} + w_n \end{bmatrix} \quad (6)$$

Step 4. Determination of the matrix of boundary approximate areas (*G*).

BAA for each criterion is determined according to the expression:

$$g_i = \left(\prod_{j=1}^{m} v_{ij}\right)^{1/m} \quad (7)$$

where v_{ij} represents the elements of the weighted matrix (*V*).

After calculating the value of g_i according to the criteria, a matrix of borderline approximate values *G* (8) of *n x* 1 format is formed (*n* represents the total number of criteria by which the choice of the offered alternatives is made).

$$G = [g_1 \quad g_2 \cdots \quad g_n] \tag{8}$$

Step 5. Calculation of the distance matrix of alternatives elements from BAA (*Q*).

$$Q = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1n} \\ q_{21} & q_{22} & \cdots & q_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ q_{m1} & q_{m2} & \cdots & q_{mn} \end{bmatrix} \tag{9}$$

Удаљеност алтернатива од граничне апроксимативне вредности области (q_{ij}) одређује се као разлика елемената отежане матрице (*V*) и вредности ГАО (*G*). The distance of the alternatives from the boundary approximate value of the area (q_{ij}) is determined as the difference of the elements of the weighted matrix (*V*) and the BAA value (*G*).

$$Q = V\text{-}G = \begin{bmatrix} V_{11} & V_{12} & \cdots & V_{1n} \\ V_{21} & V_{22} & \cdots & V_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ V_{m1} & V_{m2} & \cdots & V_{mn} \end{bmatrix} - [g_1 \quad g_2 \quad \cdots \quad g_n] = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1n} \\ q_{21} & q_{22} & \cdots & q_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ q_{m1} & q_{m2} & \cdots & q_{mn} \end{bmatrix} \tag{10}$$

where g_i represents the BAA for criterion *Ci*, v_{ij} represents the elements of the weighted matrix (*V*). Belonging of the alternative A*i* to the approximate area (*G*, G^+ or G^-) is determined based on the expression:

$$A_i \in \begin{cases} G^+ & if \quad q_{ij} > g_i \\ G & if \quad q_{ij} = g_i \\ G^- & if \quad q_{ij} < g_i \end{cases} \tag{11}$$

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

Step 6. Ranking of the alternatives. The calculation of the values of the criterion functions by alternatives (12) is obtained as the sum of the distances of the alternatives from the BAA (*qi*). By summing the elements of the matrix *Q* by rows, the final values of the criterion functions of the alternatives are obtained:

$$S_i = \sum_{j=1}^{n} q_{ij},\ j = 1, 2,..., n,\ i = 1, 2,..., m \tag{12}$$

3. APPLICATION OF THE MODEL

The hybrid decision-making model AHP-MABAC will show the determination of the best alternative according to certain criteria. On a concrete example, the selection of one of the four combined construction machines intended for flood prevention and remediation of the consequences caused by earthquakes will be shown, which represents the best choice for procurement to the Emergency Situations Sector, which are marked with A1, A2, A3 and A4 (for the evaluation of alternatives, the criteria were taken values of combined construction machines from four manufacturers).

3.1. Criteria description

Before starting the application of the method, the basic criteria are defined on the basis of which the best combined construction machine is selected. The basic criteria on the basis of which the best alternative will be selected are:

criterion 1 ($к_1$) – engine power in kilowatts (kW)

criterion 2 ($к_2$) – maximum speed in kilometers per hour (km/h)

criterion 3 ($к_3$) – depth of digging in meters (m) criterion 4 (κ_4) – price in thousands of euros (1000 €)

criterion 5 (κ_5) – the volume of the bucket in cubic meters (m^3)

criterion 6 (κ_6) – autonomy of work in hours (h)

Criteria $\kappa_{1,}$ $\kappa_{2,}$ $\kappa_{3,}$ κ_5 and κ_6 are criteria of the "benefit" type, and criterion κ_4 is a criterion of the "cost" type.

3.2. Calculation of the weight coefficients of the criteria

Since the criteria were defined, the conditions were met for the application of the AHP method according to the steps defined in point 2.1, whereby the weighting coefficients shown in Table 3 are obtained.

Table 3. Weight coefficients of the criteria

Criterion	Criterion weighting coefficients (W)
K_1	0.0751
K_2	0.0256
K_3	0.12197
K_4	0.40828
K_5	0.06402
K_6	0.30503

The degree of consistency of the initial decision matrix is 0.09657, which represents a deviation of less than 0.10, so it can be considered that the initial matrix of pairwise comparisons is consistent.

3.3. Choosing the best alternative

After obtaining the weight vectors, the best alternative was selected using the MABAC method. To obtain the best alternative, the steps from point 2.2 were applied. By applying the steps, the final values of the criterion functions of the alternatives shown in Table 4 are obtained.

Table 4. Ranking of alternatives

	The value of the sum of the alternatives by row	Rank of alternatives
A_1	0.3101	**1**
A_2	0.0755	**3**
A_3	0.0821	**2**
A_4	-0.2523	**4**

The results from Table 4 show that alternative A_1 is ranked as the first, that is, the most favorable, and alternative A_4 as the last, that is, the least favorable.

4. CONCLUSION

The fact is that floods and earthquakes, as natural disasters, are an actual problem of modern times. That is why it is still important to have adequate equipment, in order to act preventively, that is, to eliminate the consequences of floods and earthquakes as soon as possible.

This paper presents the application of the AHP-MABAC hybrid model in the selection of a combined construction machine for flood prevention and earthquake remediation for the needs of the Department of Emergency Situations. Upon completion of the analysis, the results show that alternative A_1 is ranked as the first, that is, the most favorable, and alternative A4 as the last, that is, the least favorable. Based on all the above, it can be concluded that these methods can be used to successfully make a decision when choosing these types of funds. This research provides only an initial framework for the further continuation of the research, that is, a more detailed elaboration of the criteria and their weighting coefficients.

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