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Fuzzy DIBR II - MABAC model for flood prevention: A case study of the river Veliki Rzav

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Abstract

This paper presents a hybrid multicriteria decision-making (MCDM) model that integrates the fuzzy DIBR II (Defining Interrelationships Between Ranked Criteria II) method with the MABAC (Multi-Attributive Border Approximation Area Comparison). The proposed model addresses the problem of selecting an appropriate flood protection method for Arilje, Republic of Serbia. Flooding in this region results from the overflow of the Veliki Rzav river, which lacks constructed water structures for flood protection. The study considers three alternative flood protection solutions: sand-filled bags, mobile freestanding plastic systems, and mobile freestanding metal systems. The fuzzy DIBR II method was used to define the weighting coefficients of the criteria within a group decision-making framework. Next, the MABAC method was applied to rank the proposed alternatives. Finally, the results were validated through sensitivity analysis and comparative analysis. The validation confirmed that the developed hybrid model produces stable and reliable results.

Keywords: Multicriteria decision-making (MCDM), Defining Interrelationships Between Ranked Criteria II (DIBR II), Multi-Attributive Border Approximation Area Comparison (MABAC), Flood prevention.

1. Introduction

Flooding is one of the most destructive natural disasters, alongside earthquakes, droughts, wildfires, and severe storms. Globally, floods are the most frequent natural hazard, accounting for approximately 40%, followed by tropical cyclones (20%), earthquakes, and droughts (15%) (Social capital: the invisible face of resilience, 2016). In recent literature, flood protection technologies and decision-making processes have received considerable attention due to the rising frequency and severity of flooding emergencies worldwide.

[#] The initial version of the research was published at the 7th Security and Crisis Management - Theory and Practice (SeCMan), Belgrade, Serbia (Borota et al., 2021).

Flood protection is a complex task because it primarily protects human lives and their movable and immovable property, the environment, cultural heritage, and economic activities. Flood protection strategies are highly contextual, depending on local hydrological (Choi et al., 2021; Huang et al., 2022; Knighton et al., 2021), geomorphological (Ali et al., 2022; Piacentini et al., 2020; Walczykiewicz and Skonieczna, 2020), and socioeconomic factors (Ajiboye and Orebiyi, 2021; Edamo et al., 2022; Manzoor et al., 2022). Among frequently used methods, structural solutions, including sand-filled bags, mobile barriers, and watercourse management, have received much attention due to their adaptability to different flood scenarios. Each method offers distinct advantages and limitations in terms of cost, ease of deployment, and long-term reliability (Bakhtiari et al., 2023).

In essence, the flood protection is based on two concepts: the concept of active protection and, the concept of passive flood protection. Active flood protection measures are, as the name implies, actions taken to reduce the negative impacts of flooding. These include the projects such as regulating watercourses and basin areas that increase riverbed capacity, constructing frontal reservoirs and retentions, and setting up relief and peripheral channels to control the water regime. Passive protection measures are those that have no effect on reducing the peak of a flood wave or managing it, but do provide physical protection of water in protected areas. Embankments are the most common form of passive flood control.

When it comes to the territory of Serbia, it is estimated that floods potentially endanger about 18% of the territory, primarily along the Danube, Tisa and Sava, followed by Morava, Drina, Kolubara, Timok, and so on (Water management strategy on the territory of the Republic of Serbia until 2034, 2017), Planning, building, reconstructing, and rehabilitating facilities that safeguard protected resources are all essential for flood protection. Thus, 3506.94 km of embankments, 25,765 km of canal network, 149 pumping stations, 58 dams and a number of protective water facilities on 1st order waters were recorded in Serbia (Order on determining the operational plan for flood defense for 2021, 2020). In some localities, no water facilities have been built for flood protection; however, due to changes in the hydrological regime of high waters, changed meteorological conditions due to climate change and anthropogenic action on coastal parts of watercourses as well as in the riverbed, floods are recorded as the cause of damage. One of such locations is the municipality of Arilje, through which the river Veliki Rzav flows.

The municipality of Arilje is located in the western part of Serbia in the basin of the clean mountain rivers Veliki Rzav and Moravica, next to the main Požega - Ivanjica road. According to the configuration of the land, the relief is hilly and mountainous. Around the river Moravica, a belt of plains is represented in a narrow belt. The river Veliki Rzav flows into the river Moravica in Arilje and is its largest tributary. The characteristic values of the hydrological parameters of the river Veliki Rzav are shown in Table 1.

Table 1. Characteristic values of hydrological parameters Veliki Rzav (Preliminary flood risk assessment for the territory of the Republic of Serbia, 2019)

Hydrological station	Stationary (km)	Medium flow (m^3/s)	$Q_{1\%}$ (m^3/s)	$Q_{0,1\%}$ (m^3/s)
Radobuđa / Roge	7.35	6.090	353	646
Arilje	2.2	7.913	306	510

The operational plan for flood defense for 2021 (Order on determining the operational plan for flood defense for 2021, 2020) established that on the territory of Arilje, on Veliki Rzav, there are no water facilities built for protection against the harmful effects of water, i.e., for protection against floods. As flooding of parts of the settlement of Arilje from the high level of waters of Veliki Rzav has been recorded in the past, there is a probability of flooding in the future as well. In the floods that occurred in 2014 and 2016 in Arilje, the settlement of Gruda and some other settlements were flooded, and an area of 700ha with 300 people were endangered (Preliminary flood risk assessment for the territory of the Republic of Serbia, 2019). The crossing of IB-class state road 21 between Požega, Arilje, and Ivanjica with the river Veliki Rzav is an essential concern for flood prevention and communication issues.

The selection of appropriate flood protection systems often requires complex decision-making processes that require integrating a range of criteria, including cost-effectiveness, environmental impact, and implementation feasibility (Hamidifar et al., 2024). Multicriteria decision-making (MCDM) methods have shown effective in addressing such challenges (Lyu et al., 2023). Over the last five years, 2,693 peer-reviewed papers containing the flooding/flood/flood, protection, and MCDM keywords were discovered using the EBSCO Discovery Service. For example, method such as the MABAC (Multi-Attributive Border Approximation Area Comparison) is being used in flood risk management to support objective and transparent decision-making (Tabarestani and Afzalimehr, 2021b). The MABAC method evaluates alternatives using a multi-dimensional scoring approach, providing practical insights for selecting optimal solutions in water management projects (Hadian et al., 2022; Tabarestani and Afzalimehr, 2021a; Tešić et al., 2023). In contrast to the MABAC approach, the Defining Interrelationships Between Ranked Criteria II (DIBR II) method is relatively new and has only been used in a few studies to far.

Despite advancements in decision-support methodologies, there is limited research addressing the specific challenges faced by small urban centers like Arilje, which lack existing water infrastructure for flood protection. Given that Arilje is missing an established flood protection system, there is a possibility that protected values might be damaged and that Arilje and the surrounding communities may flood as a result of Veliki Rzav's overflow. In the event that a flood takes place in this area, this paper discusses the problem of choosing the type of flood protection against the overflow of the river Veliki Rzav, and analyzes the best flood protection options.

This paper evaluates an alternative approach for Arilje's protection in the case that forecast suggests an increase in the water level of the Veliki Rzav River. Given that there is no water infrastructure on the river for flood protection (embankments, breakwaters, etc.), three types of movable flood protection are analyzed. In this process, the paper aims to bridge this gap by applying the fuzzy DIBR II and MABAC methods to evaluate and select the most appropriate flood protection strategy for the city, contributing to the growing body of knowledge on integrated flood risk management.

The paper is organized into several sections. The second section outlines the applied methodology, while the third section presents a case study. The findings are validated in the fourth and fifth sections.

2. Description of the methods applied

This section of the paper provides a detailed description of the hybrid model. As the fuzzy DIBR II and MABAC methods were applied in this study, the flowchart is illustrated in Figure 1. The DIBR II method was fuzzified due to the uncertainties in determining the weight coefficients of the criteria. In contrast, the MABAC method was not fuzzified, as experts determined that the evaluation of alternatives based on criteria could be effectively represented using crisp values without significant challenges.

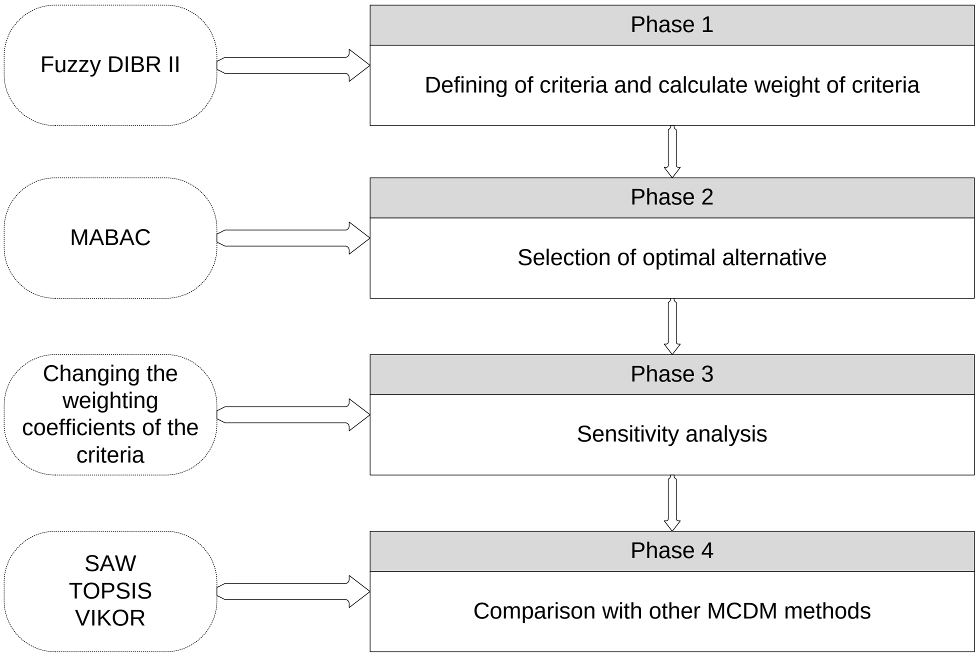

Figure 1. Flowchart of the fuzzy DIBR II – MABAC model

2.1 Triangular fuzzy number

Lotfi Zadeh developed the fundamental ideas of fuzzy logic in the 1960s with a number of groundbreaking publications (Zadeh, 1965; Zadeh, 1972; Zadeh, 1973). Today, fuzzy logic is well-developed, and is commonly used in scenarios involving uncertainty (Božanić and Pamučar, 2010). Figure 2 shows the triangular fuzzy number used in the DIBR II fuzzification method.

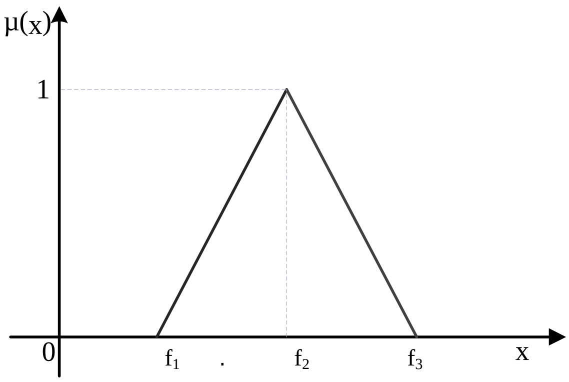

Figure 2. Triangular fuzzy number $\tilde{F}$ (Pamučar et al., 2011)

Values f_1 and f_3 represent the left and right distribution of the confidence interval of fuzzy number $\tilde{F}$, while f_2 represents the place where $\mu(x)$ has a maximum value (*1*).

2.2 Group fuzzy Defining Interrelationships Between Ranked Criteria II (DIBR II)

The DIBR II method was developed by Božanić and Pamučar (2023), where its application using crisp values was demonstrated. The fuzzification of the DIBR II method, incorporating triangular fuzzy numbers for individual decision-making, was first presented by Tešić et al. (2024). The steps of the fuzzy DIBR II method in the context of group decision-making are outlined below:

Step 1: Identification of the criteria $C=\left\{C_1,C_2,C_3...,C_n\right\}$.

Step 2: Determining the importance of each of the identified criteria, where experts rank the criteria based on their perceived importance.

Step 3: Defining the relationship between criteria ($\vartheta_{n-1,n}$), where each expert assigns values representing the relationships between criteria:

$$\tilde{\omega}_1:\tilde{\omega}_2=\tilde{\vartheta}_{1,2}:1\mapsto\frac{\tilde{\omega}_1}{\tilde{\omega}_2}=\tilde{\vartheta}_{1,2} \tag{1}$$

$$\tilde{\omega}_2:\tilde{\omega}_3=\tilde{\vartheta}_{2,3}:1\mapsto\frac{\tilde{\omega}_2}{\tilde{\omega}_3}=\tilde{\vartheta}_{2,3} \tag{2}$$

...

$$\tilde{\omega}_{n-1}:\tilde{\omega}_n=\tilde{\vartheta}_{n-1,n}:1\mapsto\frac{\tilde{\omega}_{n-1}}{\tilde{\omega}_n}=\tilde{\vartheta}_{n-1,n} \tag{3}$$

$$\tilde{\omega}_1:\tilde{\omega}_n=\tilde{\vartheta}_{1,n}:1\mapsto\frac{\tilde{\omega}_1}{\tilde{\omega}_n}=\tilde{\vartheta}_{1,n} \tag{4}$$

where $\tilde{\omega}$ represents the fuzzified value of the weight coefficient of the criterion.

The relationship between the criteria ($\tilde{\vartheta}_{n-1,n}$) is defined by experts. Experts individually compare criteria and define the relationships by first assigning a value that they believe represents the most likely relationship between two criteria (f_2). If an expert is uncertain about their evaluation, they can specify a possible deviation from the assigned value, which is represented as the left and right bounds of a triangular fuzzy number.

Step 4: Defining the relationship between the most significant and other criteria.

$$\tilde{\omega}_2=\frac{\tilde{\omega}_1}{\tilde{\vartheta}_{1,2}} \tag{5}$$

$$\tilde{\omega}_3=\frac{\tilde{\omega}_1}{\tilde{\vartheta}_{1,2}\cdot\tilde{\vartheta}_{2,3}} \tag{6}$$

...

$$\tilde{\omega}_n=\frac{\tilde{\omega}_1}{\tilde{\vartheta}_{1,2}\cdot\tilde{\vartheta}_{2,3}\cdot...\cdot\tilde{\vartheta}_{n-1,n}} \tag{7}$$

Step 5: Determination of the value of the weight coefficient of the most significant criterion.

$$\tilde{\omega}_1=\frac{1}{1+\frac{1}{\tilde{\vartheta}_{1,2}}+\frac{1}{\tilde{\vartheta}_{1,2}\cdot\tilde{\vartheta}_{2,3}}+\cdots+\frac{1}{\tilde{\vartheta}_{1,2}\cdot\tilde{\vartheta}_{2,3}\cdot\ldots\cdot\tilde{\vartheta}_{n-1,n}}} \tag{8}$$

Step 6: Determination of the value of the weight coefficient of the other criteria (Eqs. (5) to (7)).

Step 7: Defuzzification of the value of the weight coefficient of the criteria.

$$defF=((f_3-f_1)+(f_2-f_1))/3+f_1 \tag{9}$$

Step 8: Determining the quality of the relationship between the criteria, that is, the relationship between the deviation values (V_n) and the control value (ω_n^k), which must satisfy the condition that $0\leq V_n\leq 0.1$:

$$V_n=\left|1-\frac{\omega_n}{\omega_n^k}\right| \tag{10}$$

$$\omega_n^k=\frac{\omega_1}{\vartheta_{1,n}} \tag{11}$$

Step 9: Aggregation of the obtained weight coefficients into one value. In the final step, the calculated weight values are aggregated using the Bonferroni aggregator (Bonferroni, 1950).

$$BM^{p,q}(\omega_1,\omega_2,...,\omega_k)=\left(\frac{1}{k(k-1)}\sum_{\substack{e,u=1\\e\neq u}}^{k}\omega_e^p\omega_u^q\right)^{\frac{1}{p+q}} \tag{12}$$

where k is the number of experts, p,q ≥ 0 are the stabilization parameters of Bonferroni aggregator, e and u are the e-th or u-th expert, where 1 ≤ e, u ≤ k.

2.3. Multi Attributive Border Approximation area Comparison method (MABAC)

The MABAC method is one of the newer methods. It was first published in 2015 in Pamučar and Ćirović (2015). The solution procedure using this method is explained in six steps:

The first step is the evaluation of alternatives by criteria, expression 1.

$$X=\begin{matrix} & \begin{matrix} C_1 & C_2 & ... & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ ... \\ A_m \end{matrix} & \begin{bmatrix} x_{11} & x_{12} & ... & x_{1n} \\ x_{11} & x_{22} & & x_{2n} \\ ... & ... & ... & ... \\ x_{1m} & x_{2m} & ... & x_{mn} \end{bmatrix} \end{matrix} \tag{13}$$

where *m* represents the number of alternatives and *n* is the total number of criteria

In the second step, the matrix is normalized. Normalization is performed depending on the type of criteria.

For beneficial type criteria:

$$t_{ij}=\frac{x_{ij}-x_i^-}{x_i^+-x_i^-} \tag{14}$$

For cost type criteria:

$$t_{ij}=\frac{x_{ij}-x_i^+}{x_i^--x_i^+} \tag{15}$$

that $x_i^+ = \max(x_1, x_2, ..x_m)$: maximum values of the observed criterion by alternatives and $x_i^- = \min(x_1, x_2, ..x_m)$: minimum values of the observed criterion by alternatives

The third step is the calculation of the elements of the weighted matrix which is calculated according to expression (4) as follows:

$$v_{ij}=w_i\cdot t_{ij}+w_i \tag{16}$$

where t_{ij} represents the elements of the normalized matrix and ω_i - the weight coefficient of the criterion

In this way a weighted matrix V was obtained:

$$V=\begin{bmatrix} \omega_1\cdot t_{11}+\omega_1 & \omega_2\cdot t_{12}+\omega_2 & ... & \omega_n\cdot t_{1n}+\omega_n \\ \omega_1\cdot t_{21}+\omega_1 & \omega_2\cdot t_{22}+\omega_2 & ... & \omega_n\cdot t_{2n}+\omega_n \\ ... & ... & ... & ... \\ \omega_1\cdot t_{m1}+\omega_1 & \omega_2\cdot t_{m2}+\omega_2 & ... & \omega_n\cdot t_{mn}+\omega_n \end{bmatrix} \tag{17}$$

In the fourth step, the matrix of boundary approximate areas is determined (G):

$$g_i=\left(\prod_{j=1}^{m}v_{ij}\right)^{1/m} \tag{18}$$

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

The fifth step is the calculation of the elements of the distance of the alternatives from the boundary approximate domain, which is determined as the difference between the element of the weighted matrix (V) and the value of the approximate domains (G) according to the following expressions:

$$Q = V - G = \begin{bmatrix} v_{11} - g_1 & v_{12} - g_2 & \dots & v_{1n} - g_n \\ v_{21} - g_1 & v_{22} - g_2 & \dots & v_{2n} - g_n \\ \dots & \dots & \dots & \dots \\ v_{m1} - g_1 & v_{m2} - g_2 & \dots & v_{mn} - g_n \end{bmatrix} \tag{19}$$

where: g_i -boundary approximative area for criterion C_i; v_{ij} - element of weighted matrix *V*.

In the sixth step, the alternatives are ranked, which is calculated as the sum of the distances of the alternatives from the boundary approximate domains q_i. The final values of the criterion functions of the alternative are given by the following expression:

$$S_i = \sum_{j=1}^{n} q_{ij},\ j = 1,2,...,n,\ i = 1,2,...,m \tag{20}$$

3. Case study

3.1 Criteria description and weighting coefficient calculation

Four experts were engaged in this study, and they established six evaluation criteria. These criteria are listed below in order of importance, from most to least significant:

- C1-*availability at a given moment* refers to the alternatives being provided and stored. Table 2 presents the scale used to assess availability.

Table 2. Scale for determining availability at a given moment

Linguistic descriptor	Abbreviation	Assigned numerical value	Description
Not available	NA	1	Not available on the territory of Serbia.
Not currently available	NCA	5	It is not currently available on the spot.
Available	A	10	It is available.

- C2-*speed of flood protection execution*. This criterion of the speed of defense implementation does not include the time spent for the delivery of mobile equipment from the warehouse to the place of flood defense. Speed is expressed in hours per meter length.
- C3-*the possibility of reuse* is a criterion in the sense that the alternative is not consumable but can be reused as needed. Table 3 presents the scale used to assess the possibility of reuse.

Table 3. Scale for assessing the possibility of reuse

Linguistic descriptor	Abbreviation	Assigned numerical value	Description
Can not be used	CN	1	Can not be used.
Damaged	D	2	Most of the equipment is damaged.
Small damage	SD	3	A small part of the equipment is damaged without the possibility of repair.
Minor damage	MD	4	Equipment has minor damage that can be removed.
Can be used	C	5	It can be used again. The equipment is not damaged.

- C4-for this criterion, *the number of hired workers* for the installation of protection in the length of 2 m and 0.5 m in height is considered.
- C5-this criterion is important in the sense that in addition to labor (human) to perform the work *requires special machinery*, such as trucks, cranes, forklifts and so on. Table 4 presents the scale used to assess the need for additional machinery.

Table 4. Scale for assessing the need for additional machinery

Linguistic descriptor	Abbreviation	Assigned numerical value
Does not need additional machinery	NN	3
Desirable machinery	DM	8
Mandatory mechanization	MM	10

- C6-*the cost* of equipment. A value corresponding to a length of 2 m was taken in the calculation.

In the following, the experts compared the defined criteria, as shown in Table 5.

Table 5. Expert assessments of the criteria relationship

Criteria	Expert 1	Expert 2	Expert 3	Expert 4
C1/C2	(1.2, 1.3, 1.4)	(1, 1, 1.1)	(1, 1.1, 1.2)	(1.5, 1.5, 1.5)
C2/C3	(1.5, 1.7, 1.9)	(2.5, 2.7, 3)	(2, 2.3, 2.5)	(1.1, 1,2, 1.3)
C3/C4	(1.5, 1.7, 1.9)	(1.2, 1.4, 1.6)	(1,8, 2.1, 2.5)	(1.2, 1.4, 1.6)
C4/C5	(1.3, 1.3, 1.3)	(1.5, 1.6, 1.7)	(1.2, 1.5, 1.8)	(2, 2.1, 2.3)
C5/C6	(2, 2.5, 3)	(1.7, 2, 2.3)	(1.3, 1.6, 1.8)	(2, 2.5, 3)

After the application of the fuzzy DIBR II method, Table 6 presents the weight coefficients of the criteria.

Table 6. Weight coefficients of the criteria

Criteria	Criteria weight coefficients (ω_j)
C1	0.358
C2	0.296
C3	0.158
C4	0.100
C5	0.064
C6	0.024

3.2 Defining alternatives and selection of the best one

For the purposes of this research, three alternatives were identified and are described below.

Alternative 1 (A1) - Bags filled with sand. Properly installed sandbag barriers can effectively prevent or reduce flood damage. To achieve optimal protection, it is crucial that the bags are properly filled, positioned, and aligned. While various materials can be used as filling, sand is the most commonly used due to its ease of handling and proven effectiveness.

Alternative 2 (A2) - Plastic self-standing assembly elements. The NOAQ Boxwall is a freestanding mobile barrier (Figure 3) designed for flood protection. It is particularly well-suited for urban and city environments and can be installed on various surfaces, including asphalt, grass, and soil. These elements are engineered to provide protection against water at a height of 0.5 meters per meter of barrier length.

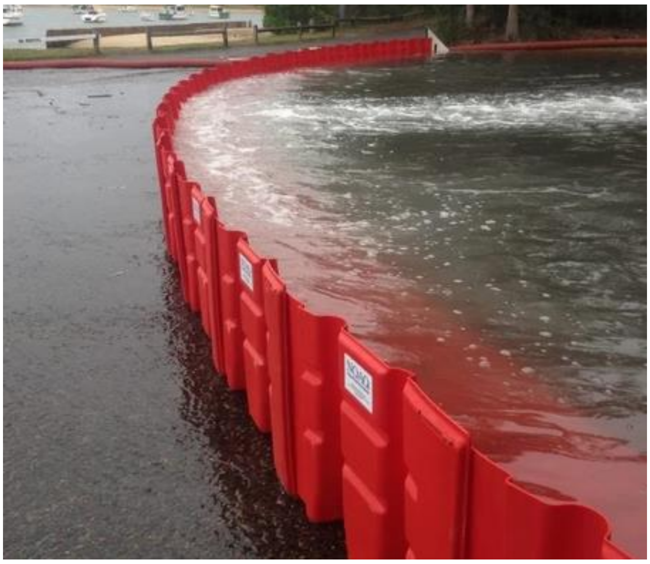

Figure 3. Plastic self-standing assembly elements
(Source: https://buyaquasafe.com/collections/noaq/products/noaq-box-wall)

Alternative 3 (A3) - Pre-assembled metal panels. Flood defense systems built with prefabricated, demountable metal panels have gained popularity in recent years (Figure 4). The panels are rectangular and set on vertical rails, forming a solid barrier against water incursion. Metal panels must be used in combination with a parapet wall that is at least 40 cm high and has openings to support vertical columns as well as grooves for panel security.

Figure 4. Pre-assembled metal panels
(Source: https://www.gradnja.rs/metalna-barijera-za-odbranu-od-poplava/)

The evaluation of alternatives based on criteria is presented in the initial decision matrix (Table 7)

Table 7. The initial decision matrix

Alternatives/Criteria	C1	C2	C3	C4	C5	C6
A1	A	0.2	CN	4	NN	2300
A2	NA	0.15	SD	2	NN	23000
A3	NCA	0.3	MD	6	DM	82000

After applying the steps of the MABAC method, the ranking of alternatives was determined, as shown in Table 8.

Table 8. The ranking of alternatives

Alternatives/Criteria	S_i	Rank
A1	0.223	1
A2	0.113	2
A3	-0.153	3

Based on the MABAC method, the ranking of alternatives was performed. The results from Table 8 indicate that alternative A1 is ranked first while alternative A3 is ranked as the most unfavorable because it is ranked third. The small difference between alternatives A1 and A2 suggests that alternative A2 should also be considered under certain conditions. It is important to note the context of the decision-making process, as the criteria are designed for a situation where flood protection needs to be provided as quickly as possible. If the decision were made well in advance of a potential flood, the criteria and their relative importance might differ, which could affect the ranking of alternatives.

4. Sensitivity analysis

Sensitivity analysis is a crucial step in validating the results (Tešić and Khalilzadeh, 2024; Kawecka et al., 2024). Various approaches to sensitivity analysis exist (Biswas et al., 2024; Więckowski and Sałabun, 2025), one of which involves adjusting the weight coefficients. In this study, sensitivity analysis was conducted by reducing the weight coefficient of the most influential criterion by 10%, while evenly increasing the weight of the other criteria in each scenario. The scenarios (S) of weight coefficient changes are shown in Table 9.

Table 9. Sensitivity analysis scenarios

	ω_1	ω_2	ω_3	ω_4	ω_5	ω_6
S1	0.322	0.303	0.165	0.107	0.071	0.031
S2	0.286	0.310	0.172	0.114	0.078	0.038
S3	0.251	0.317	0.179	0.121	0.085	0.045
S4	0.215	0.325	0.187	0.129	0.093	0.053
S5	0.179	0.332	0.194	0.136	0.100	0.060
S6	0.143	0.339	0.201	0.143	0.107	0.067
S7	0.107	0.346	0.208	0.150	0.114	0.074
S8	0.072	0.353	0.215	0.157	0.121	0.081
S9	0.036	0.360	0.222	0.164	0.128	0.088
S10	0.004	0.367	0.229	0.171	0.135	0.095

The ranking of alternatives based on the different scenarios is presented in Figure 5. As shown in Figure 5, the ranking of alternatives does not change under the first two scenarios. However, starting from scenario S3, a shift occurs in the rankings, with alternatives A1 and A2 switching positions. This change is expected, given the small difference in the criterion functions between alternatives A1 and A2. The results indicate that the model is sensitive to changes in weight coefficients, yet it can tolerate possible errors in defining the weight coefficients of the criteria.

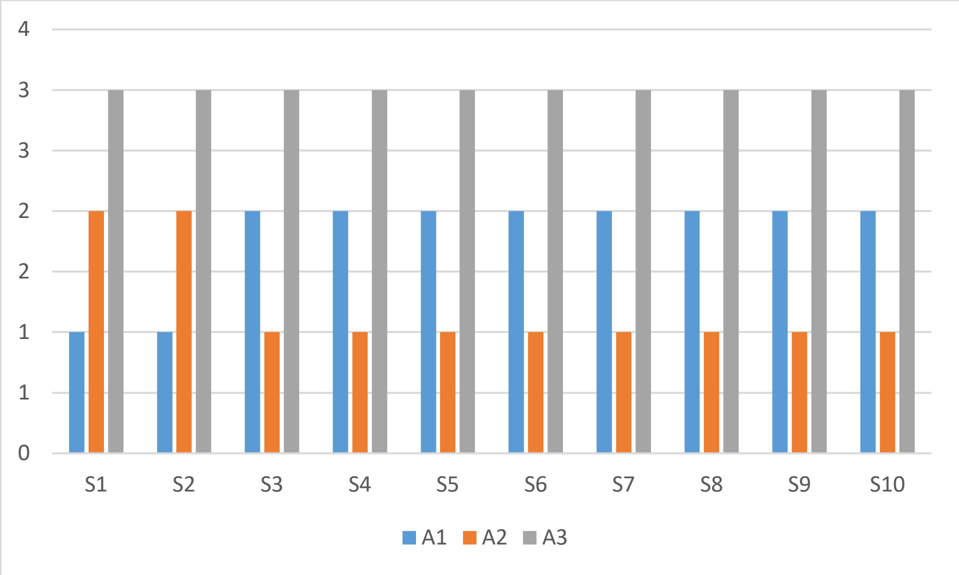

Figure 5. Ranking of alternatives using different scenarios

5. Comparative analysis

Comparative analysis has become an integral part of MCDM models and it is widely used in the literature (Božanić et al., 2023, Abid and Saqlain, 2024, Baig et al., 2024). In this study, a comparative analysis was performed using the results obtained from the SAW (Simple Additive Weighting) method (Churchman and Ackoff, 1954), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method (Hwang and Youn, 1981), and VIKOR (Višekriterijumska optimizacija I KOmpromismo Rešenje) method (Opricović, 1998). The results of this analysis are shown in Figure 6.

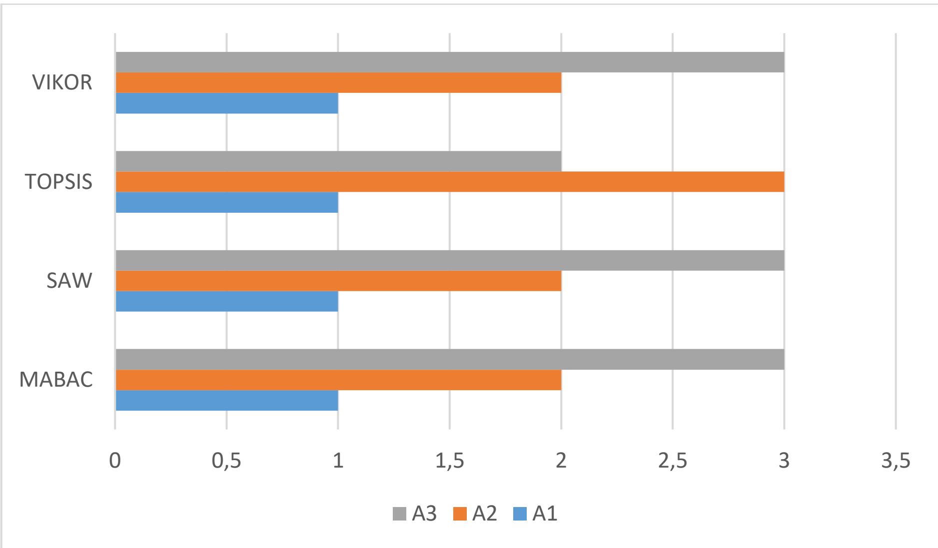

Figure 6. Ranking of alternatives using different MCDM methods

As seen in Figure 6, the SAW and VIKOR methods produce the same results as the MABAC method. However, the TOPSIS method shows a deviation, with alternatives A2 and A3 switching positions in the ranking. Since the ranking of alternative A1 is consistent across all methods and most of the methods produce similar results, it can be concluded that the model provides stable and reliable outcomes.

5. Conclusion

This paper demonstrated that MCDM methods can be a practical and effective tool for planning flood defenses. By setting clear criteria and evaluating different flood protection options, these methods make it easier to decide on the best approach for areas without existing defenses, like Arilje. This kind of structured decision-making can help improve the effectiveness of flood protection in vulnerable locations.

This paper successfully applied the DIBR II method in a fuzzy environment within the context of group decision-making for the first time. The results demonstrated that the method produced reliable results and is highly effective for allowing communication with experts. Additionally, the MABAC method was used to rank the alternatives. Validation through sensitivity and comparative analyses confirmed that the hybrid fuzzy DIBR II–MABAC model is effective in evaluating the proposed flood protection alternatives.

Flood protection remains an important topic for further research. Selecting an appropriate flood protection system in a different context - such as when protection equipment is secured well in advance - would present a new challenge for researchers. In such cases, the relative importance of criteria might change, and additional flood protection alternatives, such as deepening the riverbed, may appear as reasonable option.

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