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A Multi-Criteria Decision-Making Model for Pontoon Bridge Selection: An Application of the DIBR II-NWBM-FF MAIRCA Approach

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Abstract: In military operations, the proficient overcoming of water barriers is paramount, with sub-optimal execution potentially leading to significant human and equipment casualties. In this context, global armed forces accord considerable emphasis to the selection of appropriate mechanisms for water obstacle overcoming. This study elucidates the adoption of a Multi-Criteria Decision-Making (MCDM) approach for the selection of optimal pontoon bridge sets for military applications. Criteria identification was undertaken by seven distinguished experts, leading to the determination of weight coefficients using the Defining Interrelationships Between Ranked criteria II (DIBR II) method. Expert assessments were subsequently aggregated utilizing the Normalized Weighted Bonferroni Mean (NWBM) operator. The Multi-Attributive Ideal-Real Comparative Analysis (MAIRCA) method, operationalized within the Fermatean Fuzzy (FF) environment, was harnessed for the discernment of the best alternative. An analysis of the sensitivity of the study's findings with respect to variations in criteria weighting, coupled with a comparative exploration, led to the inference that the proposed MCDM model boasts stability. However, it was noted that the model exhibits sensitivity to shifts in criteria weight coefficients, underscoring its utility as a valuable aid for decision-makers, especially in the domain of pontoon bridge set selection.

Keywords: Multi-Criteria Decision-Making; Defining Interrelationships Between Ranked criteria II; Normalized Weighted Bonferroni Mean; Fermatean Fuzzy (FF); Multi-Attributive Ideal-Real Comparative Analysis; Selection

1 Introduction

Historically, as organized human communities manifested an intrinsic desire to expand territories, the imperative to overcome natural water barriers arose. These barriers, formidable in their essence, demanded innovation from these communities: initial solutions were found in swimming, which later evolved to the construction of varied watercraft. Coinciding with the inception of rudimentary military units, specialized brigades dedicated to circumventing these water impediments were established, equipped with intricate apparatuses tailored for the task [1]. Present-day military operations worldwide acknowledge the gravity of this combat action, which, given its intricate nuances, is often regarded as one of the most formidable combat challenges [1]. Furthermore, many military entities, beyond amphibious capabilities, are endowed with pontoon parks, encompassing an array of technical assets such as pontoons, vehicles, watercraft, and auxiliary tools, conceptualized for scaffold and bridge assembly [1, 2].

For decision-makers, the procurement of such assets designed to overcome water impediments presents a multifaceted challenge. The complexity arises from the plethora of dimensions or criteria by which these means are evaluated. Effective decision-making in this domain necessitates reliance on intricate tools for decision support, especially those adept at handling uncertainty and imprecision. Given the multidimensional nature of the problem at hand, the Multi-Criteria Decision-Making (MCDM) methods emerge as the apt tools for informed decision-making. These methods incorporate a variety of mathematical models and tools within the ambit of MCDM.

Typically, the resolution of an MCDM problem can be delineated into distinct steps: 1) Criteria identification pivotal to decision-making; 2) Ascertainment of criteria weight coefficients, denoting the influence exerted by each criterion on the final judgement; 3) Establishment of the initial decision-making matrix; 4) Employment of mathematical strategies for discerning the optimal solution; and 5) Selection of said optimal solution. To date, an extensive array of methods have been introduced. Some cater to determining criteria weight coefficients [3–8], while others focus on the discernment of the optimal choice amongst a myriad of possibilities [3, 9–20]. The application of MCDM methodologies across diverse sectors has been documented extensively in previous research, as elucidated in Table 1.

Table 1. The problem of choice using MCDM methods – A brief literature review

Field of Application	References
Military	[21–32]
Transportation-engineering	[33–39]
Economy	[40–43]
Industry	[44–47]
Medicine	[48–51]
Agricultural and biological-sciences	[52–56]

In this paper, the DIBR II-NWBM-FF MAIRCA MCDM model (Figure 1) is presented for the selection of the optimal set of pontoon bridge for the needs of the military.

The model consists of the following stages: 1) Identification of criteria and their weight coefficients using the DIBR II method; 2) Choosing the optimal alternative using the FF MAIRCA method; 3) Sensitivity analysis of the output results of the method; and 4) Comparative analysis.

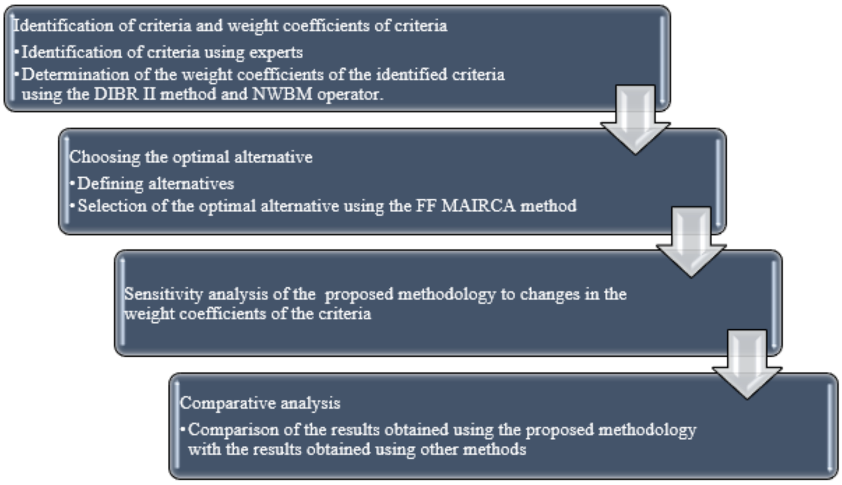

Figure 1. MCDM model DIBR II-NWBM-FF MAIRCA

Note: This figure was prepared by the authors.

2 Methodology

In alignment with the phases delineated in Figure 1, the subsequent sections elucidate the methods integrated within the MCDM model. Additionally, the I operators, pivotal for the aggregation of expert opinions, are detailed.

2.1 DIBR II Method

Introduced in 2023, the DIBR II method for determining weight coefficients of criteria is expounded in the study [8]. This method was devised to address the limitations observed in prior methodologies for calculating criteria weight coefficients. To date, its implementation has been documented in two distinct studies. In their research, Božanić and Pamučar [8] deployed this method in the domains of car procurement and the evaluation of social media efficacy. Subsequently, Božanić et al. [57] harnessed the method to determine weight coefficients of criteria, specifically while categorising methods and techniques within Lean organisation systems management.

A concise mathematical representation of the DIBR II method is presented below [8].

Step 1. Identification of criteria $K = \{K_1, K_2, ..., K_n\}$.

Step 2. Defining the rank of criteria based on importance $K_1 > K_2 > ... > K_n$.

Step 3. Defining the relationship between the criteria.

$$\omega_1 : \omega_2 = \upsilon_{1,2} : 1 \mapsto \frac{\omega_1}{\omega_2} = \upsilon_{1,2} \tag{1}$$

$$\omega_2 : \omega_3 = \upsilon_{2,3} : 1 \mapsto \frac{\omega_2}{\omega_3} = \upsilon_{2,3} \tag{2}$$

...

$$\omega_{n-1} : \omega_n = \upsilon_{n-1,\mathrm{n}} : 1 \longmapsto \frac{\omega_{n-1}}{\omega_n} = \upsilon_{n-1,\mathrm{n}} \tag{3}$$

$$\omega_1 : \omega_n = \upsilon_{1,\mathrm{n}} : 1 \mapsto \frac{\omega_1}{\omega_n} = \upsilon_{1,\mathrm{n}} \tag{4}$$

Step 4. Defining the relationship between the most important and other criteria.

$$\omega_2 = \frac{\omega_1}{\upsilon_{1,2}} \tag{5}$$

$$\omega_3 = \frac{\omega_2}{\upsilon_{2,3}} = \frac{\omega_1}{\upsilon_{1,2} \cdot \upsilon_{2,3}} \tag{6}$$

...

$$\omega_n = \frac{\omega_1}{\upsilon_{1,2} \cdot \upsilon_{2,3} \cdots \upsilon_{n-1,\mathrm{n}}} \tag{7}$$

Step 5. Determination of the weight coefficient of the most important criterion.

$$\omega_1 = \frac{1}{1 + \frac{1}{\upsilon_{1,2}} + \frac{1}{\upsilon_{1,2} \cdot \upsilon_{2,3}} + \cdots + \frac{1}{\upsilon_{1,2} \cdot \upsilon_{2,3} \cdots \upsilon_{n-1,\mathrm{n}}}} \tag{8}$$

Step 6. Determination of the weight coefficients of the remaining criteria.

Step 7. Evaluation of the quality of defined relationships.

In order to determine the quality of the defined relationships, it is necessary that the deviation D_n of the criteria K_n is in the range $0 \leq D_n \leq 0.1$, where:

$$D_n = \left| 1 - \frac{\omega_n}{\omega_n^k} \right| \tag{9}$$

$$\omega_n^k = \frac{\omega_1}{\upsilon_{1,n}} \tag{10}$$

and where the values should be approximately equal, that is, a deviation of up to 10% is allowed.

2.2 FF MAIRCA Method

Within the context of this investigation, enhancements to the MAIRCA method [18] were made, incorporating FRFSs. Detailed explications of these sets can be found in studies [58–60]. The mathematical architecture of the FF MAIRCA method, as illustrated in studies [18, 59], is delineated as follows:

Step 1. A linguistic scale was defined for the evaluation of alternatives, grounded on FRFSs.

Step 2. Every alternative $A = \{A_1, A_2, ..., A_i\}$ was evaluated by each expert $E = \{E_1, E_2, ..., E_k\}$ according to all criteria $C = \{C_1, C_2, ..., C_j\}$ using the established linguistic scale. Subsequently, the initial decision matrix $\otimes E_{ijk} = \left\{\varphi_{E_{ijk}}, \gamma_{E_{ijk}}\right\}$ was derived for each expert, wherein $\varphi_{E_{ijk}}$ represents the degree of membership,$\gamma_{E_{ijk}}$ represents the degree of non-membership of FF number $\otimes E_{ijk}$, and $0 \leq \left(\varphi_{(x)}\right)^3 + \left(\gamma_{(x)}\right)^3 \leq 1$.

Step 3. Expert opinions were aggregated and the initial decision matrix was attained, accomplished through the application of Eq. (11) [59].

$$\otimes X_{ij} = FFWA(\otimes E_{ij1}, \otimes E_{ij2}, ..., \otimes E_{ijp}) = \left(\frac{1}{p} \sum_{k=1}^{p} \varphi_{E_{ijk}}, \frac{1}{p} \sum_{k=1}^{p} \gamma_{E_{ijk}} \right) \tag{11}$$

where, p represents the number of experts.

Step 4. The initial decision matrix $\otimes N_{ij}$ was normalized, achieved using Eq. (12) [59].

$$\otimes N_{ij} = \begin{cases} \otimes X_{ij}, j = \text{ Benefit} \\ \text{Com}\left(\otimes X_{ij}\right), j = \text{ Cost} \end{cases} \tag{12}$$

Step 5. The probability of opting for specific alternatives P_{A_i} was discerned through Eq. (13) [18].

$$P_{A_i} = \frac{1}{i} \tag{13}$$

where, i represents the total number of alternatives.

Step 6. The matrix of theoretical weights $\otimes T_{pj}$ was determined Eq. (14).

$$\otimes T_{pj} = \left(\otimes t_{p1}, \otimes t_{p2}, ..., \otimes t_{pj}\right), \, where \otimes t_{pj} = P_{A_i}.\omega_j \tag{14}$$

Step 7. The matrix of real weights $\otimes T_{rij}$ was determined Eq. (15).

$$\begin{bmatrix} C_1 & C_2 & \cdots & C_j \end{bmatrix} \otimes T_{rij} = \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_i \end{bmatrix} \begin{bmatrix} \otimes t_{r11} & \otimes t_{r12} & \cdots & \otimes t_{r1j} \\ \otimes t_{r21} & \otimes t_{r22} & \cdots & \otimes t_{r2j} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes t_{ri1} & \otimes t_{ri2} & \cdots & \otimes t_{rij} \end{bmatrix} \tag{15}$$

where, $\otimes t_{rij} = \omega_j \cdot \otimes N_{ij}$.

Step 8. A gap matrix $\otimes G_{ij}$ was computed, contrasting theoretical and real weights, based on Eq. (16).

$$\otimes G_{ij} = \otimes T_{pj} - \otimes T_{rij} \tag{16}$$

Step 9. The expected solution $\otimes Q_i$ was extrapolated via Eq. (17).

$$\otimes Q_i = \sum_{j=1}^{p} \otimes G_{ij} \tag{17}$$

Step 10. Alternatives were sorted in accordance with the positive score function $\psi^p\left(\otimes Q_i\right)$ Eq. (17) [59] of the expected solution. It is paramount to note that the least score function value designates the top-rated alternative, and the converse holds true.

$$\psi^p\left(\otimes Q_i\right) = 1 + \psi\left(\otimes Q_i\right) \text{ where } \psi\left(\otimes Q_i\right) = \left(\varphi_{Q_i}\right)^3 - \left(\varphi_{Q_i}\right)^3 \tag{18}$$

Step 11. The dominance index for the foremost-ranked alternative $I_{D,1-i}$ was discerned utilizing Eq. (19) and the dominance threshold T_D through Eq. (20).

$$I_{D,1-i} = \frac{Q_i - Q_{fr}}{Q_{lr}} \tag{19}$$

where, Q_{fr} represents the first-ranked alternative, Q_{lr} represents the last-ranked alternative and Q_i represents the alternative being considered.

$$T_D = \frac{i-1}{i^2} \tag{20}$$

where, i represents the total number of alternatives.

For the solution to be considered valid, the relationship must satisfy $I_{D,1-i} \geq T_D$. If not met, the alternative's rank must be amended. Such an alternative will bear a mark (1*) adjacent to its rank, indicating that while it is not the foremost choice, it remains a potential optimal solution. This implies that decision-makers might still consider it as a viable resolution to the MCDM problem.

2.3 The Normalized Weighted Bonferroni Mean (NWBM) Operator [61]

This operator was adopted in the study to aggregate the opinions of seven experts when determining the weight coefficients of criteria using the DIBR II method Eq. (21).

$$NWBM^{\mathrm{p,q}}\left(\mathrm{y}_1, y_2, \ldots, y_n\right) = \left(\sum_{i,j=1}^{n} \frac{\omega_i \omega_j}{1-\omega_i} y_i^p y_j^q\right)^{\frac{1}{p+q}} \tag{21}$$

where, $y_1, y_2, \ldots, y_n$ represent a set of positive numbers, $p, q \geq 0$ are stabilization parameters of the function, and ω_{ij} denote weight coefficients of experts' competencies.

3 Results

The first step of the proposed methodology entailed criteria identification. Through a comprehensive analysis of extant literature and consultations with seven field experts $E = \{E_1, E_2, \ldots, E_7\}$, five distinct criteria $C = \{C_1, \mathrm{C}_2, \mathrm{C}_3, \mathrm{C}_4\}$ were established, as detailed in Table 2.

Table 2. Criteria for choosing a pontoon bridge set

The Name of the Criteria	Description of Criteria	Type of Criteria
K_1 - The price	It represents the cost price of the pontoon bridge set in dollars.	Cost
K_2 - Carrying capacity of a bridge or one pontoon in a scaffold	The basic feature of every pontoon bridge I is the load capacity in tons. Depending on the carrying capacity, technical combat means that can overcome the obstacle are defined.	Benefit
K_3 - Throughput	It represents the number of military equipment that can cross a pontoon bridge, the largest possible length of one set, in a unit of time.	Benefit
K_4- The possibility of assembling scaffolding	Indicates the number and size of scaffolds that can be assembled from one set of pontoon bridges.	Benefit
K_5- Complexity of construction and devices on pontoons	It represents the complexity of the construction of the pontoon bridge set, from the aspect of influence on the handling of the devices on the pontoons. The more complex the assets, the more complicated the handling.	Cost

Subsequent to the criteria delineation, the DIBR II method was employed to define these criteria further. Seven experts from the domain determined the significance of each criterion, yielding respective weighting coefficients $\omega_k^E = (0.155, 0.135, 0.140, 0.130, 0.145, 0.135, 0.160)$. Eqs. (1)-(10) were employed to compute the weight coefficients of the criteria for every expert, as displayed in Table 3.

Table 3. The weight coefficients of the criteria defined by experts

	$\mathbf{C_1}$	$\mathbf{C_2}$	$\mathbf{C_3}$	$\mathbf{C_4}$	$\mathbf{C_5}$
E_1	0.256035	0.213363	0.193966	0.176333	0.160303
E_2	0.239677	0.208414	0.19849	0.189038	0.164381
E_3	0.249726	0.208105	0.198195	0.180177	0.163797
E_4	0.256035	0.213363	0.193966	0.176333	0.160303
E_5	0.244059	0.212225	0.192932	0.183744	0.16704
E_6	0.253182	0.210985	0.200938	0.182671	0.152226
E_7	0.249631	0.215199	0.195636	0.177851	0.161683

Opinions from experts were aggregated through the NWBM aggregator, specifically using Eq. (21). This aggregation process produced the final values of the weight coefficients of the criteria shaping the subject choice, as elucidated in Table 4.

Following the ascertainment of the weight coefficients of criteria, alternatives were identified. These alternatives were manifested as four distinct pontoon bridge sets available in the market, each possessing unique attributes $A = \{A_1, A_2, A_3, A_4\}$.

Table 4. The final values of the weight coefficients of the criteria for the selection of the pontoon bridge set

	$\mathbf{C_1}$	$\mathbf{C_2}$	$\mathbf{C_3}$	$\mathbf{C_4}$	$\mathbf{C_5}$
ω_j	0.256035	0.213363	0.193966	0.176333	0.160303

Step 1. Respecting the steps of the proposed FF MAIRCA methodology, Table 5 shows the linguistic scale employed by experts to evaluate each alternative against all criteria.

Table 5. FF linguistic scale

Scale	**FFN**
Apsolutly satisfies (AS)	$(0.9, 0.1)$
Satisfies (S)	$(0.75, 0.25)$
Partially satisfying (PS)	$(0.65, 0.35)$
Partially unsatisfactory (PU)	$(0.35, 0.65)$
Not satisfy (NS)	$(0.25, 0.75)$
Apsolutly not satisfy (ANS)	$(0.1, 0.9)$

Step 2. Seven experts evaluated all alternatives using a linguistic scale (Table 5), and their decision matrices are given in Table 6.

Table 6. Decision matrix of experts (E_k)

$\mathbf{E}_1$	$\mathbf{K}_1$	$\mathbf{K}_2$	$\mathbf{K}_3$	$\mathbf{K}_4$	$\mathbf{K}_5$	$\mathbf{E}_2$	$\mathbf{K}_1$	$\mathbf{K}_2$	$\mathbf{K}_3$	$\mathbf{K}_4$	$\mathbf{K}_5$	$\mathbf{E}_3$	$\mathbf{K}_1$	$\mathbf{K}_2$	$\mathbf{K}_3$	$\mathbf{K}_4$	$\mathbf{K}_5$
A_1	AS	S	S	AS	PS	A_1	AS	AS	S	AS	S	A_1	S	S	S	S	S
A_2	S	AS	AS	PS	S	A_2	S	AS	AS	PS	AS	A_2	AS	AS	AS	PS	S
A_3	S	PS	PU	S	PU	A_3	S	PS	AS	S	PU	A_3	S	PU	PU	S	PU
A_4	PU	S	S	PU	AS	A_4	PU	S	S	PU	AS	A_4	PU	AS	S	AS	AS
$\mathbf{E}_4$	$\mathbf{K}_1$	$\mathbf{K}_2$	$\mathbf{K}_3$	$\mathbf{K}_4$	$\mathbf{K}_5$	$\mathbf{E}_5$	$\mathbf{K}_1$	$\mathbf{K}_2$	$\mathbf{K}_3$	$\mathbf{K}_4$	$\mathbf{K}_5$	$\mathbf{E}_6$	$\mathbf{K}_1$	$\mathbf{K}_2$	$\mathbf{K}_3$	$\mathbf{K}_4$	$\mathbf{K}_5$
A_1	AS	S	S	AS	PS	A_1	AS	S	S	AS	AS	A_1	AS	S	S	AS	PS
A_2	S	AS	S	S	S	A_2	S	AS	AS	PS	S	A_2	AS	AS	AS	PS	S
A_3	S	PS	PU	S	PU	A_3	S	AS	AS	S	PU	A_3	S	PS	PU	S	PU
A_4	PU	S	S	S	AS	A_4	PU	S	S	AS	AS	A_4	PU	S	S	PU	AS
						$\mathbf{E}_7$	$\mathbf{K}_1$	$\mathbf{K}_2$	$\mathbf{K}_3$	$\mathbf{K}_4$	$\mathbf{K}_5$						
						A_1	AS	AS	AS	AS	AS						
						A_2	S	AS	AS	S	AS						
						A_3	AS	PS	PU	S	PU						
						A_4	PS	S	S	PU	AS						

Step 3. By means of Eq. (11), the aggregation of expert opinions was carried out, which leads to the initial decision-making matrix (Table 7).

Table 7. Initial decision matrix

	$\mathbf{K}_1$		$\mathbf{K}_2$		$\mathbf{K}_3$		$\mathbf{K}_4$		$\mathbf{K}_5$	
A_1	0.8786	0.1214	0.7929	0.2071	0.7714	0.2286	0.8786	0.1214	0.7500	0.2643
A_2	0.7929	0.2071	0.9000	0.1000	0.8786	0.1214	0.6786	0.3214	0.7929	0.2071
A_3	0.7714	0.2286	0.6857	0.3286	0.5071	0.4929	0.7500	0.2500	0.3500	0.6500
A_4	0.3929	0.6071	0.7714	0.2286	0.7500	0.2500	0.5643	0.4357	0.9000	0.1000

Step 4. By applying Eq. (12), the initial decision matrix was normalized, and the normalized values are presented in Table 8.

Step 5. The probability of choosing certain alternatives was determined using Eq. (13) and the value 0.25 was obtained.

Step 6. Applying Eq. (14) leads to the matrix of theoretical weights (Table 9).

Step 7. The matrix of real weights was obtained by applying Eq. (15) and presented in Table 10.

Step 8. The matrix of the gap between theoretical and real weights obtained by applying Eq. (16) is presented in Table 11.

Table 8. Normalized matrix

	$\mathbf{K_1}$		$\mathbf{K}_2$		$\mathbf{K}_3$		$\mathbf{K}_4$		$\mathbf{K_5}$	
A_1	0.1214	0.8786	0.7929	0.2071	0.7714	0.2286	0.8786	0.1214	0.2643	0.7500
A_2	0.2071	0.7929	0.9000	0.1000	0.8786	0.1214	0.6786	0.3214	0.2071	0.7929
A_3	0.2286	0.7714	0.6857	0.3286	0.5071	0.4929	0.7500	0.2500	0.6500	0.3500
A_4	0.6071	0.3929	0.7714	0.2286	0.7500	0.2500	0.5643	0.4357	0.1000	0.9000

Table 9. Matrix of theoretical weights

	$\mathbf{K}_1$		$\mathbf{K}_2$		$\mathbf{K}_3$		$\mathbf{K}_4$		$\mathbf{K}_s$	
T_p	0.0625	0.0625	0.0530	0.0530	0.0490	0.0490	0.0453	0.0453	0.0403	0.0403

Table 10. The matrix of real weights

	$\mathbf{K_1}$		$\mathbf{K}_2$		$\mathbf{K}_3$		$\mathbf{K}_4$		$\mathbf{K_5}$	
A_1	0.0076	0.0549	0.0420	0.0110	0.0378	0.0112	0.0398	0.0055	0.0106	0.0302
A_2	0.0129	0.0496	0.0477	0.0053	0.0431	0.0060	0.0307	0.0145	0.0083	0.0319
A_3	0.0143	0.0482	0.0363	0.0174	0.0249	0.0242	0.0339	0.0113	0.0262	0.0141
A_4	0.0379	0.0246	0.0409	0.0121	0.0368	0.0123	0.0255	0.0197	0.0040	0.0362

Table 11. The matrix of gap between theoretical and real weights

	$\mathbf{K}_1$		$\mathbf{K}_2$		$\mathbf{K}_3$		$\mathbf{K}_4$		$\mathbf{K}_5$	
A_1	0.0549	0.0076	0.0110	0.0420	0.0112	0.0378	0.0055	0.0398	0.0296	0.0101
A_2	0.0496	0.0129	0.0053	0.0477	0.0060	0.0431	0.0145	0.0307	0.0319	0.0083
A_3	0.0482	0.0143	0.0167	0.0356	0.0242	0.0249	0.0113	0.0339	0.0141	0.0262
A_4	0.0246	0.0379	0.0121	0.0409	0.0123	0.0368	0.0197	0.0255	0.0362	0.0040

Table 12. The expected solutions

	$\otimes \boldsymbol{Q_i}$	
A_1	0.1122	0.1372
A_2	0.1073	0.1427
A_3	0.1144	0.1348
A_4	0.1049	0.1451

Step 9. The expected solutions are calculated using Eq. (17), and the obtained values are shown in Table 12.
Step 10. Applying Eq. (18) leads to the score function based on which the ranking is made (Table 13).

Table 13. Score function and initial ranking of alternatives

	$\psi^{\boldsymbol{P}}(\otimes \boldsymbol{Q}_i)$	**Rank**
A_1	0.9988	3
A_2	0.9983	2
A_3	0.9990	4
A_4	0.9981	1

Step 11. By applying Eqs. (19) and (20), the dominance index for top-ranked alternative $I_{D,1-i}$ and the threshold of dominance T_D are determined (Table 14).

Table 14. The values of the dominance index and the threshold of dominance

	$\boldsymbol{I_{D,1-i}}$	$\boldsymbol{T_D}$
A_1	0.0007	
A_2	0.0002	
A_3	0.0010	0.1875
A_4	0.0000	

Drawing insights from Table 14, it was concluded that the preliminary ranking coincided with the final ranking of alternatives. Specifically, alternative A_4 emerged as the top-ranked choice, while alternative A_3 was positioned as the least preferred option.

4 Sensitivity and Comparative Analysis

A sensitivity analysis concerning the introduced methodology was undertaken, focusing primarily on variations in the weight coefficients of the criteria, as delineated in studies [22, 24, 26, 28]. Within this analytical framework, 14 distinct scenarios of weight change were articulated, as illustrated in Figure 2.

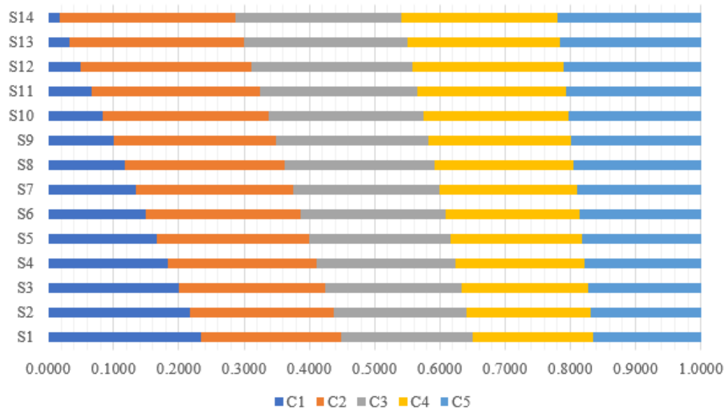

Figure 2. Scenarios of changing the weight coefficients of the criteria
Note: This figure was prepared by the authors.

By applying the scenarios shown in Figure 2, the following ranks of alternatives were obtained (see Figure 3).

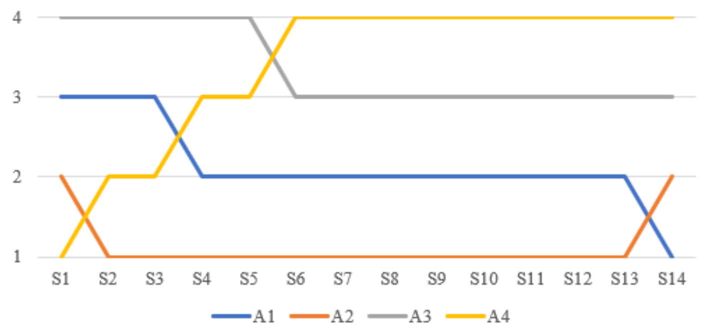

Figure 3. The ranks of the alternatives obtained by applying the defined scenarios
Note: This figure was prepared by the authors.

Drawn from the changes in the rankings of the alternatives, as presented in Figure 4, it was inferred that the proposed FF MAIRCA method exhibited pronounced sensitivity to shifts in the weight coefficients of the criteria. Hence, when these coefficients are defined by experts, heightened vigilance is necessitated to discern the interrelationships among the criteria influencing the selection of the optimal alternative.

A comparative analysis ensued, juxtaposing the outcomes derived from the proposed methodology with those presented in studies [58, 60]. Employing the initial decision matrix (Table 7) and invoking mathematical constructs such as FFWPA (Fermatean Fuzzy weighted power average), FFWPG (Fermatean Fuzzy weighted power geometric), FFWA (Fermatean Fuzzy weighted average), and FFWG (Fermatean Fuzzy weighted geometric) operators, rankings of alternatives were formulated, as enumerated in Table 15.

The rankings acquired using the FF MAIRCA method and those presented in Table 15 were subsequently analyzed through the computation of the Spearman's correlation coefficient, as discussed in studies [26, 62] (see Figure 4).

The data visualized in Figure 4 underscored the robustness of the proposed model. Specifically, the correlation coefficients displayed a proclivity towards a positive ideal correlation, suggesting the model's stability and its capacity to yield accurate results.

Table 15. Alternative ranks obtained using Fermatean Fuzzy weighted operators

	FFWA	FFWG	FFWPA	FFWPG
A_1	3	4	3	3
A_2	2	1	1	1
A_3	4	3	4	4
A_4	1	2	2	2

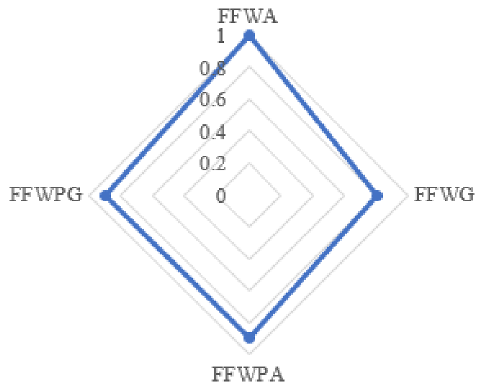

Figure 4. The values of Spearman's rank correlation coefficient
Note: This figure was prepared by the authors.

5 Conclusions

Through the application of the intricate MCDM model, encompassing DIBR II - NWBM - FF MAIRCA, a selection process for pontoon bridge sets was undertaken. The findings and insights derived from this study shed light on the nuances of decision-making across varied contexts. A pivotal aspect of the research involved leveraging the DIBR II method to ascertain weight coefficients of the criteria. This element was instrumental in delineating priorities among diverse criteria, grounded in the aggregated perspectives of seven experts via the NWBM operator. Subsequently, the weight coefficients were integrated into the FF MAIRCA method, showcasing an innovative enhancement of the MAIRCA approach utilizing FF sets. Serving as the foundation for alternative ranking, this method also facilitated the identification of the optimal solution for the MCDM quandary. The findings pinpointed alternative A_4 as the prime solution for the MCDM challenge associated with pontoon bridge set selection.

Further scrutiny was directed towards the sensitivity of the model relative to shifts in the weight coefficients of the criteria. It was inferred that pronounced sensitivity was exhibited, underscoring the imperative of meticulous weight definition by experts to maintain model precision in practical scenarios. For validation, a comparative analysis juxtaposed the results with the FFW operator's outcomes. Conclusions drawn verified the stability and accuracy of the proposed methodology, reinforcing its efficacy and applicability within the pontoon bridge set selection milieu.

This study furnishes a robust framework tailored for decisions concerning water obstacle traversal tools, with an emphasis on pontoon bridge sets. However, it is salient to highlight the necessity for rigorous criteria weight delineation to bolster the model's stability and accuracy. The devised methodology stands as a potential asset for decision-makers overcoming water obstacle challenges in military settings, aiming to bolster the selection efficacy of military resources.

The primary constraint of this investigation pivots on the quantity of criteria steering the choices. Future research trajectories allude to this limitation, advocating a granular exploration of criteria, coupled with the integration of theories adept at handling vagueness and uncertainties inherent in conventional MCDM methodologies.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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