THE DIBR-SAW MODEL FOR THE SELECTION OF LOCATION FOR OVERCOMING WATER BARRIER WITH DEEP DRAFT

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Abstract: *In this paper the issue of selecting a location for overcoming water barrier with deep draft using hybrid model based on the Defining Interrelationships Between Ranked criteria (DIBR) method and the Simple Additive Weighting (SAW) method is discussed. The DIBR method is used to define the weight coefficients of criteria, while the SAW method is used to rank the alternatives. The criteria conditioning the overcoming of water barrier with deep draft are elaborated through the paper. Five experts from the field of overcoming water barriers participated in the research.*

Key words: *location, multi-criteria decision-making, DIBR, SAW*

1. INTRODUCTION

Decision-making is very significant segment of an individual's life (Adegbola, 2023; Debnath & Ghosh, 2021), as well as of various organizational systems (Pamucar et al., 2012; Badi et al., 2023). The importance of making the best decision can be clearly observed through the increased number of research related to the topic of decision-making (Tripathy, 2023). In contemporary scientific literature, there has been a significant increase in the number of methods dealing with multi-criteria decision-making (Si & Ganguly, 2021).

Crossing rivers, as well as water barriers in general, is very complex tactical action, especially when the defended barrier is reinforced with artificial, primarily mine-explosive and fortification obstacles (Bozanic, 2017). Therefore, the Army pays special attention to the decision-making process (Pamucar et al., 2011a). During combat operations, unit commanders find themselves in the situations in which they have to make a large number of more or less significant decisions (Pamucar et al., 2016). The main goal is to make the best decision in the shortest period of time, because making the wrong decision can have catastrophic

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consequences that are reflected in the loss of personnel and material resources (Pamucar & Bozanic, 2010). In this context, the application of multi-criteria decision-making methods presents an essential support to the mentioned process (Boskovic et al., 2023). For the purposes of this paper, a mathematical model is developed that supports making the decision on the selection of a location for overcoming water barrier with deep draft.

A place of overcoming water barrier with deep draft is intended for tank crossing with a maximum depth of 2.1 meters (Pifat, 1980), and it has a number of specifics that need to be ensured in order to successfully overcome water barrier. The location is selected based on several criteria, using the DIBR and the SAW methods. The essence of the problem lies in the selection of one variant of the decision, which is chosen based on the comparison of all elaborated options (alternatives). In certain situations, there is a possibility that a commander will not have enough knowledge and experience, which can result in making a wrong or lower-quality decision (Pamucar et al. 2011b). By applying a multi-criteria decision-making model, this problem is greatly reduced.

2. DESCRIPTION OF THE DECISION-MAKING MODEL

This paper presents a decision-making supporting model for selecting a location for overcoming water barrier with deep draft using the DIBR and SAW methods.

In the first phase of the model, the criteria are identified and the weight coefficients of the criteria are defined. Hence, certain criteria are defined that influence the solution of the given problem. Using the DIBR method, the weight coefficients of the defined criteria are calculated. In the second phase, the alternatives are defined and the best one is selected using the SAW method. The description of the applied methods is provided below.

2.1. DIBR method

The DIBR method was first presented in the paper by Pamucar et al. (2021). In the following part will be presented the procedure for implementing the DIBR method through 5 steps (Pamucar et al., 2021):

Step 1: Ranking the criteria according to their significance

If there is a defined set of n criteria C = {C1, C2, C3, ..., Cn}, it is necessary to rank those criteria according to significance - from the most significant to the least significant criterion. For the purpose of easier presentation of the methodology, the criteria can be ordered according to significance as C1 > C2 > C3 > … > Cn, where n presents the total number of criteria in the set C.

Step 2: Comparison of criteria and definition of mutual relations

The values that a decision maker assigns to the criteria during the comparison are marked with δhy, repectively, when comparing the criterion C1 with the criterion C2, the value δ12 is assigned, when comparing the criterion C2 with the criterion C3, the value δ23 is assigned, and so on until the last criterion.

All the values obtained δ_{12}, δ_{23}, ..., $\delta_{n-1,n}$ и $\delta_{1,n}$ should meet the condition where $\delta_{n-1,n}, \delta_n \in [0, 1]$. Based on this, the following relations between the criteria can be defined:

$$\varphi_1 : \varphi_2 = (1 - \delta_{12}) : \delta_{12} \tag{1}$$

$$\varphi_2 : \varphi_3 = (1 - \delta_{23}) : \delta_{23} \tag{2}$$

$$\dots$$

$$\varphi_{n-1} : \varphi_n = (1 - \delta_{n-1,n}) : \delta_{n-1,n} \tag{3}$$

$\varphi_1 : \varphi_n = (1 - \delta_{1,n}) : \delta_{1,n}$ (4)

The equations (1) - (4) and the value $\delta_{n-1,n}$ can be observed as the ratios by which the decision maker divides the total interval, whose value is 100%, on the two observed criteria. For example, if the assigned value for δ_{12} = 0,45 this means that the criterion C_1 has 55% of significance, and the criterion C_2 has 45% significance.

Step 3: Defining relations for the calculation of weight coefficients

After the comparison of the criteria and the definition of mutual relations have been performed, the expressions can be derived for defining the weight coefficients of the criteria $\varphi_2, \varphi_3, ..., \varphi_n$. From the equations (1) - (3), follows next:

$$\varphi_2 = \frac{\delta_{12}}{(1-\delta_{12})}\varphi_1 \tag{5}$$

$$\varphi_3 = \frac{\delta_{23}}{(1-\delta_{23})}\varphi_2 = \frac{\delta_{12}\delta_{23}}{(1-\delta_{12})(1-\delta_{23})}\varphi_1 \tag{6}$$

...

$$\varphi_n = \frac{\delta_{n-1,n}}{(1-\delta_{n-1,n})}\varphi_{n-1,n} = \frac{\delta_{12}\cdot\delta_{23}\cdot\ldots\cdot\delta_{n-1,n}}{(1-\delta_{12})(1-\delta_{23})\cdot\ldots\cdot(1-\delta_{n-1,n})}\varphi_1 = \frac{\prod_{i=1}^{n-1}\delta_{i,i+1}}{\prod_{i=1}^{n-1}(1-\delta_{i,i+1})}\varphi_1 \tag{7}$$

Step 4: Calculation of the weight coefficient of the most influential criterion

On the basis of the equations (5) - (7) and having been met the condition where $\sum_{j=1}^{n}\varphi_j = 1$, it is possible to obain the expression for the calculation of the weight coefficient of the most influential criterion:

$$\varphi_1 = \frac{1}{1 + \frac{\delta_{12}}{(1-\delta_{12})} + \frac{\delta_{12}\delta_{23}}{(1-\delta_{12})(1-\delta_{23})} + \ldots + \frac{\prod_{i=1}^{n-1}\delta_{i,i+1}}{\prod_{i=1}^{n-1}(1-\delta_{i,i+1})}} \tag{8}$$

By applying the already defined equations (5) - (7), the values of the other weight coefficients are determined $\varphi_2, \varphi_3, ..., \varphi_n$.

Step 5: Calculation of the aggregated weight coefficients of criteria

Through the first four steps, the weight coefficients of criteria are calculated for each expert separately. In this step, the experts' opinions are aggregated into one value. The aggregation is performed using the Bonferroni Mean operator:

$$BM^{p,q}(\Phi_1, \Phi_2, \ldots, \Phi_n) = \left[\frac{1}{n(n-1)}\sum_{\substack{i,j=1 \\ i\neq j}}^{n}\varphi_i^p K \varphi_j^q\right]^{\frac{1}{p+q}} \tag{9}$$

where p,q≥0 presents stabilization parameters of the Bonferroni operator.

2.2. SAW method

The SAW method was developed by Churchman and Ackoff (1954). Although it is an older method, the results obtained with it are very similar to the results of a large part of modern methods. The same as with other methods, the initial decision-making matrix is defined at the beginning.

$$
M = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array}
\begin{array}{c}
\begin{array}{ccccc} C_1 & C_2 & C_3 & \cdots & C_n \end{array} \\
\begin{bmatrix}
x_{11} & x_{12} & x_{13} & \dots & x_{1n} \\
x_{21} & x_{22} & x_{23} & \dots & x_{2n} \\
x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn}
\end{bmatrix}
\end{array}
\tag{10}
$$

The SAW method is very simple and involves only three steps, which are presented below.

Step 1: Normalization of the initial decision-making matrix

The authors of the method did not define the type of normalization to be used. Linear normalization is used in this paper:

$$n_{ij} = \frac{x_i^{min} - x_{ij}}{x_i^{min} - x_i^{max}} \tag{11}$$

$$n_{ij} = \frac{x_i^{max} - x_{ij}}{x_i^{max} - x_i^{min}} \tag{12}$$

where x_{ij} presents the specific value of a criterion for certain alternative, x_i^{max} is the highest value of a criterion among the offered alternatives and x_i^{min} is the lowest value of a criterion among the offered alternatives. The expression (11) is applied to define benefit-type criteria. On the other hand, the expression (12) is used to define cost-type criteria.

Step 2: Weighting of normalized matrix

Weighting of normalized matrix is made according to the expression (13).

$$D = \begin{bmatrix}
v_{11} & \cdots & v_{1j} & \cdots & v_{1n} \\
\vdots & & \vdots & & \vdots \\
v_{i1} & & v_{ij} & & v_{in} \\
\vdots & & \vdots & & \vdots \\
v_{m1} & \cdots & v_{mj} & \cdots & v_{mn}
\end{bmatrix} = \begin{bmatrix}
\Phi_1 n_{11} & \cdots & \Phi_j n_{ij} & \cdots & \Phi_n n_{1n} \\
\vdots & & \vdots & & \vdots \\
\Phi_1 n_{i1} & & \Phi_j n_{ij} & & \Phi_n n_{in} \\
\vdots & & \vdots & & \vdots \\
\Phi_1 n_{m1} & \cdots & \Phi_j n_{ij} & \cdots & \Phi_n n_{mn}
\end{bmatrix} \tag{13}$$

Step 3: Summing the weighted ratings for each alternative

In this step, the weighted values for each alternative are summed up.

$$S_j = \sum_{j=1}^{m} \varphi_j x_{ij}, \tag{14}$$

j = 1, 2, ..., m,

This sum provides each alternative with certain utility. When making a decision, it should be selected the alternative with the greatest utility.

3. APPLICATION OF THE DECISION-MAKING MODEL

In order to start solving the issue with multi-criteria decision-making model, first it is necessary to define and rank the criteria in the manner described in the first step of the DIBR method. For the purposes of this paper, five experts are surveyed, who defined the criteria, ranked and compared them. According to the views of the experts, the following eight criteria are defined:

- *Depth of water barrier* (C1) - distance measured from the surface to the bottom of water barrier;
- *Speed of water barrier* (C2) - speed of water movement per unit of time [m/s];

– *Width of water barrier* (C3) - distance between the banks, measured by the surface of water obstacle;

– *Scope of works on the arrangement of the bottom* (C4) - largely depends on the geological composition of the bottom;

– *Scope of works on the arrangement of enemy bank* (C5) - works such as the arrangement of bank height, bank slope, removal of various natural and artificial obstacles on the bank, *etc*.;

– *Scope of works on the arrangement of own bank* (C6) - includes similar works as in the arrangement of the enemy's bank;

– *Conditions for masking* (C7) - the forested area should be used to the maximum for masking when preparing to overcome water barriers;

– *Access roads* (C8) - the roads allowing the access of units to and from water barrier.

The first three criteria are numerical ones, while the other criteria are of linguistic character, described by a five-point scale (1,3,5,7,9).

Based on the opinion of the experts, all the mentioned criteria are defined according to significance. The weights of criteria (φ) are obtained by applying the expressions (1) - (8). After the calculation, the weight coefficients of the criteria are aggregated using the Bonferroni Mean operator (the expression 9). The final results of the weight coefficients of the criteria are presented in the Table 1.

Table 1. Weight coefficients of the criteria *(Source: Authors)*

Criteria	Φ_i
C1	0,408
C2	0,136
C3	0,223
C4	0,071
C5	0,044
C6	0,031
C7	0,021
C8	0,028

Once the weight coefficients of the criteria are calculated, the selection of the best alternative is made. At the beginning, a decision-making matrix is created to which the SAW method is directly applied. The Table 2 shows the quantified values for 10 virtual alternatives for each criterion.

Table 2. Quantified initial decision-making matrix *(Source: Authors)*

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8
A1	2,01	0,55	351	5	1	3	4	3
A2	1,53	1,25	416	9	9	1	2	1
A3	1,68	1,61	521	3	5	9	1	5
A4	1,02	1,76	603	1	7	5	3	2
A5	1,96	1,07	498	5	3	7	5	4
A6	2,06	0,94	385	1	3	5	1	2
A7	1,48	0,56	569	7	9	9	3	3

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8
A8	1,71	1,43	618	7	5	3	4	5
A9	2,05	0,38	447	3	1	1	5	1
A10	1,88	0,24	652	9	7	7	2	4
Type of Criteria	cost	cost	cost	cost	cost	cost	benefit	benefit

By practical application of the further steps of the SAW method, the calculation is performed. Each alternative received certain utility determining its position in the ranking list. The ranking list of alternatives is given in the Table 3.

Table 3. Ranking of alternatives *(Source: Authors)*

Alternatives	Qj	Ранг
A1	0,484	2
A2	0,465	3
A3	0,363	7
A4	0,560	1
A5	0,333	8
A6	0,398	6
A7	0,438	4
A8	0,299	9
A9	0,429	5
A10	0,251	10

The results from the Table 3 show that in this particular example, the best alternative for overcoming water barrier with deep draft is the alternative A4. The alternatives A1 and A2 are in the second and third place. These could be chosen as favorable solutions in certain situations. In the last place is the alternative A10.

4. CONCLUSION

This procedure provided the conditions for quick quality decision-making in the process of selecting a location for tanks crossing water barriers with deep draft. Undoubtedly, decision-making becomes one of the key elements in creating business environment in the upcoming period, especially in the situations where human lives and material goods are at risk. Apart from the practical contribution of the paper, from the theoretical aspect, the conceptualization of a relatively new method for defining weight coefficients of criteria - DIBR, as well as its successful application in practice, is presented. The output results obtained using the SAW method show that the method can be used as a decision-making support. The greatest contribution provided by the applied model is reflected in the fact that potential errors in a decision-making process are reduced to a minimum by the use of mathematical solutions.

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