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# APPLICATION OF DIBR-TOPSIS MODEL IN SELECTING LOCATION FOR FORCED RIVER CROSSING USING AMPHIBIOUS TRANSPORTERS PTS-M

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***Abstract:*** *In this paper it has been worked out the problem of selecting the optimal location for forced river crossing using amphibious transporters PTS-M in an offensive operation. For the purpose of this research a hybrid model is developed based on two methods: the Defining Interrelationships Between Ranked criteria (DIBR) method and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. The DIBR method is applied to determine weight coefficients of criteria, while the TOPSIS method is used to rank different alternatives. Through the paper, the criteria are elaborated that condition the selection of the location for forced river crossing using amphibious transporters PTS-M. Five experts with significant experience in the field of river crossing and military operations participated in the process of research and conclusion.*

***Key words:*** *Forced river crossing place, Amphibious transporter PTS-M, Multi-criteria decision making, DIBR, TOPSIS*

## 1. INTRODUCTION

The modern environment of combat operations is characterized by a high degree of complexity, uncertainty, dynamics, uniqueness and unrepeatability, as well as other similar features (Milic et al, 2019). Therefore, there is a constant need to make more or less significant decisions, which often directly affect people's lives, which creates additional responsibility for the people who make decisions in operations, such as commanders and commanding officers at different levels (Bozanic et al, 2014). Multi-criteria decision making (MCDM) methods are applied in order to support the command staff in making optimal decisions. For the purposes of this paper, a mathematical model is developed that

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supports decision-making in selecting a location for forced river crossing using amphibious transporters PTS-M.

The forced river crossing place is one of the key points in offensive operations carried out in the zones with water obstacles (rivers). The organization of the forced river crossing place is carried out in different ways, which depends to a significant extent on the means used. An important tool in the realization of the forced river crossing is the amphibious transporter PTS-M. Amphibious transporters enable quick and efficient passage of units over rivers. Their tactical advantages include reducing transition time, minimizing the risk of losses, and increasing operational efficiency. Amphibious transporters are important in situations that require the establishment of bridgeheads or the rapid support of troops on the opposite bank, as they allow for the rapid occupation of positions and the establishment of defense. However, the organization of the forced river crossing place with amphibious transporters has its own specifics. Primarily, these are related to the fact that the embarking of stuff does not have to be done on the bank itself, but also in the places that are somewhat further from the bank. This is accomplished due to the amphibious transporters' ability to transport cargo on both land and water. This feature significantly reduces the risk when overcoming water obstacles.

In the literature so far, the application of MCDM methods for military purposes is not widely represented. Radovanovic et al. (2023; 2024) deal with the selection of different types of rifles. Devetak and Karovic (2018) work out the selection of Communications and Information System, while Tesic and Marinkovic (2023) show the selection of complex combat systems. When it comes to overcoming water obstacles, there is not much research to be found. The selection of locations for bridge crossing is discussed in several papers, such as Bozanic and Pamucar (2010), Pamucar et al. (2013) and Bozanic (2017). The selection of the forced river crossing place (without emphasizing the specifics of the application of amphibious transporters) can be found in the papers by Bozanic (2017) and Bozanic et al. (2022).

The selection of a suitable location for crossing a river with amphibious transporters at the forced river crossing is a topic that has not been discussed so far. Therefore, in this paper, a hybrid model is created based on two methods, the DIBR and TOPSIS methods. The essence of the problem is the identification of the best decision, based on the comparison of all elaborated alternatives (Bouraima et al., 2024). The MCDM methods not only simplify the decision-making process, but also provide a deeper analysis (Sing et al., 2024; Sahoo et al., 2024), allowing commanders to have quick and comprehensive insights into the complexity of the situation (Pamucar et al., 2011).

The remaining part of the paper consists of three additional units. The applied methods are described in the following section. After that, a presentation of the application of the model is made, and at the end a conclusion is provided.

## 2. DESCRIPTION OF THE DECISION-MAKING MODEL

In this paper is presented a model for supporting decision making during the selection of the forced river crossing location for amphibious transporters PTS-M based on the the DIBR and the TOPSIS method. In the first phase of the model are identified the criteria and their weight coefficients. The weight coefficients of the defined criteria are calculated using the DIBR method, while the selection of the best alternative is shown using the TOPSIS method. A description of the applied methods is given below.

### 2.1. DIBR method

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

*Step 1:* Ranking criteria according to their significance
A set of n criteria is ranked from the most significant to the least significant criterion $C_1 > C_2 > C_3 > \dots > C_n$, where *n* presents a total number of criteria in the set C.

*Step 2:* Comparison of criteria and defining their mutual relations

The values assigned to the criteria by a decision maker during the comparison are marked with $\theta_{xy}$. For example, during the comparison of the criterion $C_1$ with the criterion $C_2$ it is assigned the value $\theta_{12}$, during the comparison of the criterion $C_2$ with the criterion $C_3$ it is assigned the value $\theta_{23}$, and so on until the last criterion.

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

$$w_1 : w_2 = (1 - \theta_{12}) : \theta_{12} \tag{1}$$

...

$$w_1 : w_n = (1 - \theta_{1,n}) : \theta_{1,n} \tag{2}$$

The equations (1) and (2) and the value $\theta_{n-1,n}$ can be observed as the ratios used by a decision maker to divide the total interval with, whose value is 100%, at the two observed criterion.

*Step 3:* Calculation of the weight coefficient of the most influential criterion is performed by applying the expression (3):

$$w_1 = \frac{1}{1 + \frac{\theta_{12}}{(1-\theta_{12})} + \frac{\theta_{12}\theta_{23}}{(1-\theta_{12})(1-\theta_{23})} + \dots + \frac{\prod_{i=1}^{n-1}\theta_{i,i+1}}{\prod_{i=1}^{n-1}(1-\theta_{i,i+1})}} \tag{3}$$

*Step 3:* Calculation of the values of the other weight coefficients is performed by applying the expressions (4)-(6):

$$w_2 = \frac{\theta_{12}}{(1-\theta_{12})} w_1 \tag{4}$$

$$w_3 = \frac{\theta_{12}\theta_{23}}{(1-\theta_{12})(1-\theta_{23})} w_1 \tag{5}$$

...

$$w_n = \frac{\prod_{i=1}^{n-1}\theta_{i,i+1}}{\prod_{i=1}^{n-1}(1-\theta_{i,i+1})} w_1 \tag{6}$$

*Step 5:* Calculation of aggregated weight coefficients of criteria

In the first four steps are calculated the weight coefficients of the criteria for each expert separately. In this step is made the aggregation of the opinions of the experts into one value. The aggregation is done by applying the Bonferroni Mean operator:

$$BM^{p,q}(w_1, w_2, \dots, w_n) = \left[\frac{1}{n(n-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{n} w_i^p w_j^q\right]^{\frac{1}{p+q}} \tag{7}$$

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

### 2.2. TOPSIS method

The TOPSIS method was first presented in the paper by Hwang and Yoon (1981). The method ranks alternatives based on several criteria by comparing their distance from ideal solutions. The TOPSIS method has become one of the most widely used techniques for decision-making in complex and dynamic environments. Due to its wide application, it is not explained in detail in this paper, and in addition to the paper in which it was first published, it can be found in a number of other papers, such as Kizielewicz, B., & Sałabun (2024), Kousar et al. (2024), Biswas et al. (2024), Lukic (2023a; 2023b), etc.

## 3. APPLICATION OF THE DECISION-MAKING MODEL

In order to start solving a given problem by applying the MCDM model, it is firstly necessary to define and rank the criteria in the manner shown in the first step in the DIBR method. For this research, five experts are interviewed to define, rank, and compare the criteria. Considering that after the first round of interviews, the views of the experts were not in complete agreement, two more rounds of interviews were organized with some of the experts. Misunderstanding of the MCDM method appears as the biggest problem when conducting interviews, but this problem has been solved with additional explanations.

Based on experts views, six criteria are defined:
- *Dominance of own forces* (C1) - strength of own forces in relation to enemy forces that are directly involved in forced river crossing;
- *Transit time* (C2) - the time required for the amphibious transporter to travel from the place of embarkation to the place of disembarkation of the unit;
- *Quality of places for embarking on amphibious transporters* (C3) - conditions for masking, dispersal and protection of units while waiting for embarkation, conditions for masking embarkation on amphibious transporters;
- *Access roads* (C4) - present the roads that bring units to the river and take away the units from the river;
- *Distance of the embarkation point from the bank* (C5) – represents the distance between the embarkation point of the unit on the amphibious transporter and the bank;
- *Scope of works on the improvement of the banks* (C6) - includes works such as the regulation of the height of the bank, the slope of the bank, the removal of various natural and artificial obstacles on the bank, *etc*.

The criteria are defined under the assumption that it is possible to conduct equal fire preparation for each location.

The criteria C2 and C5 are numerical criteria, while the other criteria are of a linguistic nature, and are described by a five-level scale, as shown in the Table 1.

**Table 1:** Scale for transferring linguistic into numerical criteria

| C1, C3, C4 | Very good (VG) | Good (G) | Medium (M) | Bad (B) | Very Bad (VB) |
|---|---|---|---|---|---|
| C6 | Very Small (VS) | Small (S) | Medium (M) | High (H) | Very High (VH) |
| Numeric value | 9 | 7 | 5 | 3 | 1 |

The criteria are defined and ranked according to their importance based on the opinion of the experts. The weight coefficients of criteria (w) are calculated using the equations (1) - (6). After this calculation, the weight coefficients of the criteria are aggregated using the Bonferroni Mean operator (equation 7). The results of the weight coefficients of the criteria are presented in the Table 2.

**Table 2:** Weight coefficients of the criteria

| Criterium | *w* |
|---|---|
| C1 | 0.394 |
| C2 | 0.206 |
| C3 | 0.187 |
| C4 | 0.108 |
| C5 | 0.050 |
| C6 | 0.055 |

After the weighti coefficients of the criteria have been calculated, the selection of the most favorable alternative is made. In the first step, a decision-making matrix is created, to which the TOPSIS method is directly applied. The table 3 shows the values for 15 virtual alternatives.

**Table 3:** Initial decision-making matrix

| Initial decision-making matrix | | | | | | |
|---|---|---|---|---|---|---|
| Criteria Alternatives | C1 | C2 | C3 | C4 | C5 | C6 |
| A1 | M | 146 | B | G | 222 | VH |
| A2 | B | 168 | M | VG | 284 | M |
| A3 | VB | 237 | VG | M | 291 | VS |
| A4 | VB | 223 | G | B | 235 | H |
| A5 | G | 154 | VB | M | 168 | S |
| A6 | VG | 123 | M | G | 153 | VH |
| A7 | M | 165 | B | B | 110 | M |
| A8 | B | 200 | VG | VB | 197 | VS |
| A9 | VB | 265 | VG | M | 263 | H |
| A10 | G | 148 | G | G | 185 | S |
| A11 | M | 139 | M | VB | 162 | VH |
| A12 | VG | 170 | B | M | 97 | M |
| A13 | B | 231 | VB | VG | 246 | H |
| A14 | VB | 211 | VG | G | 200 | S |
| A15 | M | 189 | G | B | 179 | VH |
| Criteria type | benefit | cost | benefit | benefit | cost | benefit |

The calculation is carried out by the practical application of the steps of the TOPSIS method. Each alternative has been given a corresponding value determining its position in the ranking list. The ranking list of the alternatives is presented in the Table 4.

**Table 4:** Rank of alternatives

| Alternative | Relative proximity | Rank |
|---|---|---|
| A1 | 0.491 | 6 |
| A2 | 0.360 | 10 |
| A3 | 0.297 | 12 |
| A4 | 0.230 | 15 |
| A5 | 0.620 | 4 |
| A6 | 0.812 | 1 |
| A7 | 0.472 | 8 |

| Alternative | Relative proximity | Rank |
|---|---|---|
| A8 | 0.383 | 9 |
| A9 | 0.283 | 14 |
| A10 | 0.752 | 3 |
| A11 | 0.490 | 7 |
| A12 | 0.754 | 2 |
| A13 | 0.290 | 13 |
| A14 | 0.310 | 11 |
| A15 | 0.512 | 5 |

The results shown in the Table 4 indicate that in this particular case, the most optimal alternative for the forced river crossing for amphibious transporters is the alternative A6. In the second and the third place are the alternatives A10 and A12, which could be selected in specific situations. The alternative A4 is in the last place and presents the least favorable solution.

## 4. CONCLUSION

This paper presents a hybrid MCDM model intended for selecting a forced river crossing location for crossing in situations where amphibious transports are used. The specificity of the application of amphibious transporters also influenced the definition of the criteria that determine the selection of such locations. Defining the criteria is done by surveying five experts, and presents the most significant contribution of this paper. Also, an important contribution of the paper is the definition of the weight coefficients of the criteria. It is carried out using the DIBR method, which proved to be quite accessible for experts. Model testing is successfully performed with 15 alternatives, using the TOPSIS method.

This and similar models can provide significant assistance to less experienced commanders and commanding officers to make a timely and correct decision. This model should be further tested through the application of other MCDM methods, but also through the use of different approaches to defining uncertainty, such as rough numbers, fuzzy numbers, grey numbers, *etc*.

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