

A Novel MEREC and ALWAS Multi-Criteria Integration and its Application to the Evaluation of Wheeled Amphibious Armoured Vehicles

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ARTICLE INFO	ABSTRACT
Article history: Received 28 July 2026 Received in revised form 13 September 2026 Accepted 20 October 2026 Available online 27 October 2026 Keywords: Wheeled amphibious vehicle; Vehicle selection; Multi-criteria decision-making; Defense industry; MEREC; ALWAS	As modern warfare has become increasingly asymmetric, achieving significant operational capability in security, defense, offensive, and logistics has become a fundamental requirement for armed forces. Amphibious wheeled vehicles serve as a vital asset, enabling contemporary militaries to address diverse operational needs across land and water, as well as through varied terrain and climatic conditions. Selecting such a vehicle requires the simultaneous evaluation of numerous criteria including terrain adaptability and performance, amphibious capabilities, power transmission, maneuverability, communication systems, and armament. This article proposes a Multi-Criteria Decision-Making (MCDM) approach to objectively and systematically evaluate alternatives for amphibious wheeled vehicles. By normalizing the performance of various alternatives based on these selected criteria with MEREC method, this approach aims to assist armed forces in identifying the most suitable vehicle to meet their specific operational requirements with ALWAS method. This article aims to contribute to the selection of amphibious wheeled vehicles within the defense industry procurement process by introducing a decision-support framework characterized by multi-layered, traceable, and transparent principles.

1. Introduction

In the context of contemporary warfare characterized by complex, unpredictable, and often asymmetric dynamics involving diverse terrains and climates the specifications of the weaponry and equipment that modern militaries utilize or seek to acquire are constantly evolving. The inherent unpredictability of today's combat environments has caused the requirements of armed forces to shift and grow increasingly complex.

In addition, the weapon alternatives existing in the rival country's inventory are evaluated. In this way, both the supply and the countries' ability to produce with their own means are checked. As a result of these evaluations, direct supply route may be preferred. In the long term, research and development activities are aimed to provide the necessary conditions for the improvement of important criteria. Countries carry out these evaluations in line with the needs for various warfare

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weapons and equipment. Since these evaluations are multiple and contradictory, a decision-making framework is needed. In an academic context, evaluation of such tools; It is carried out by analyzing various alternatives and criteria using Multi-Criteria Decision Making (MCDM) methods [1–3]. In this study, the Method Based on the Removal Effects of Criteria (MEREC) [4] was used to determine the weights of the criteria, while the Aczel-Alsina Weighted ASsessment (ALWAS) [5] method was employed to rank the alternatives.

In this study, a decision-making framework for an evaluation on amphibious wheeled vehicles is presented. Amphibious wheeled vehicles address the defensive and offensive needs of military forces across a wide range of terrains and climatic conditions [6]. When evaluating vehicles for inclusion in their inventories, armies take into account various criteria and available alternatives. The changing nature of warfare has not only transformed the needs of armed forces but has also influenced academic research, facilitating studies tailored to these specific requirements. Consequently, this has created the possibility of addressing such unpredictable variables in an analytical manner.

This study is organized as follows: Section 2 presents the literature review. Section 3 defines the problem and the criteria. Section 4 explains the methods used in the study. Section 5 presents the results. Section 6 covers the sensitivity analysis, and Section 7 shares the conclusions.

2. Literature Review

This section provides a detailed literature review for the study. The first part examines the literature concerning the selection of military vehicles, which falls within the scope of this study. The second and third parts cover the literature related to the methodologies employed.

First, examples from the literature concerning studies that employ MCDM methodologies for military vehicles are presented. In a study focusing on Landing Platform Docks (LPDs), the AHP and ELECTRE both of which are MCDM methods were used in combination. The study provides information on AHP, ELECTRE, and the Amphibious Armored Vehicles (AAVs) examined therein. Six criteria were established for the analysis; these were defined by experts in the field of amphibious operations, who also identified the four distinct amphibious armored vehicles discussed in the paper after conducting a comprehensive review of the inventories of various militaries [7].

In another study, wheeled armored vehicles (WAVs) were examined based on their defensive characteristics using a clustering analysis method within an MCDM framework. A total of 32 criteria were utilized in the study. The number of clusters was determined via a non-hierarchical clustering method, through which the vehicles were assigned to their respective clusters. The results of the analysis indicate that the vehicles can be classified into either 3 or 8 clusters. When three clusters are considered, BTR-type vehicles and equipment designed either before or after the year 2000 are grouped together; when eight clusters are used, these groups are further subdivided [8].

Another study addresses the selection of a multi-purpose, medium-class wheeled armored combat vehicle equipped with a 4x4 drive system. This study employs the AHP and PROMETHEE II methods. To reach a final decision, the Condorcet method a group decision-making technique was also incorporated into the evaluation process. In the paper, four distinct alternatives are evaluated based on 14 different criteria [9].

A study in the literature, which provides a comprehensive examination of tanks, armored personnel carriers (APCs), and armored combat vehicles (ACVs) selected from the extensive product range of the Turkish defense industry, utilizes Fuzzy AHP and TOPSIS. Furthermore, the paper discusses various types of military operations and the Turkish defense industry, while also analyzing the purposes for which these vehicles are employed by the armed forces and the combat environments in which they are deployed. A total of 23 criteria were considered to evaluate 28 alternatives [10].

The "Priorities Observed from Gaussian Attitude of Alternatives" (PrOPPAGA) method was applied to the evaluation of a wheeled armored vehicle intended for use by the Brazilian Marine Corps (BMC). Based on the defense doctrine of the Brazilian Marine Corps (BMC), four alternatives were evaluated against ten criteria [11].

A study contributes to the literature by employing a fuzzy MCDM approach utilizing 11 criteria and 4 alternatives to determine an optimal landing plan for an amphibious operation, a type of military operation involving the use of amphibious vehicles [12].

Research based on fuzzy sets has continued to emerge in the literature. Building upon the operational framework of the MULTIMOORA approach a classic MCDM method this study integrates the spherical fuzzy ratio method, the spherical fuzzy reference method, and the spherical fuzzy full multiplicative form. Finally, dominance theory is applied to consolidate the results into a single ranking. The study evaluates four alternative military armored vehicles based on five distinct criteria using the Spherical Fuzzy MULTIMOORA method [13].

In another study based on fuzzy sets, the EDAS method is employed, utilizing Type-1 fuzzy sets; trapezoidal fuzzy numbers are selected to represent evaluations provided by military experts. The study assesses 5 alternatives against 6 criteria [14].

In conclusion, the literature includes studies on MCDM for situations where objective data is available, as well as studies on fuzzy MCDM based on various types of fuzzy sets for situations where such data cannot be obtained with expert opinion. A summary overview of the literature is provided in Table 1. Tables 2 and 3, which follow, contain summaries of the literature regarding the methods employed in this study.

Table 1
Literature Summary for Military Vehicle Selection

Year	Title of Manuscript	References	Sector	Methods
2020	A decision-making model proposal (aav) for selection of amphibious attack vehicles for landing platform dock (lpd) by integrated MCDM methods	[7]	Defense Industry	AHP - ELECTRE
2019	Cluster Analysis of Multicriteria-Classified Wheeled Armored Vehicles= Kerekes harcjárművektöbbszempontú értékelésének klaszteranalízise	[8]	Defense Industry	Cluster Analysis MCDM
2025	Application of the AHP and PROMETHEE II individual decision-making methods and the Condorcet group decision-making method in the selection of a multipurpose armored wheeled combat vehicle	[9]	Defense Industry	AHP - PROMETHEE II
2023	Askeri operasyonlarda araç seçimi: karar verme sürecinde kullanilabilecek analitik yaklaşımlar	[10]	Defense Industry	Fuzzy AHP - TOPSIS
2022	Choice of armored vehicles on wheels for the Brazilian Marine Corps using PrOPPAGA	[11]	Defense Industry	PrOPPAGA
2020	Decision selection model of landing beach in amphibious operations exercise with Fuzzy MCDM.	[12]	Defense Industry	Fuzzy MCDM
2022	Evaluation of the Performance of Armored Military Vehicles by the Global Fuzzy MULTIMOORA Method.	[13]	Defense Industry	Fuzzy MULTIMOORA
2024	Selection of military armored vehicle using fuzzy EDAS method	[14]	Defense Industry	EDAS

Table

2

Literature table regarding the MEREC method

Year	Title of Manuscript	References	Sector	Methods
2023	Measuring performances through multiplicative functions by modifying the MEREC method: MEREC-G and MEREC-H	[15]	Logistic	MEREC-G – MEREC-H
2024	A Python Streamlit APP For the Mercec-Spotis MCDA Method: A Practical Use for Selecting Training Aircraft	[16]	Defense Industry	SPOTIS – MEREC – Streamlit Framework
2024	Operational Analysis of Unmanned Aerial Vehicles in Modern Wars' Context: A Hybrid Multicriteria Approach by MEREC–MAIRCA Methods	[17]	Defense Industry	MEREC – MAIRCA
2024	The MEREC-AROMAN method for determining sustainable competitiveness levels: A case study for Turkey	[18]	Sustainable Economy	MEREC – AROMAN
2025	Turkiye's Carbon Emission Profile: A Global Analysis with the MEREC-PROMETHEE Hybrid Method	[19]	Environmental Management	MEREC –PROMETHEE II
2025	Optimizing E-Commerce Platform Selection Using Root Assessment Method and MEREC Weighting	[20]	E-commerce	RAM – MEREC

Table 3

Literature table regarding the ALWAS method

Year	Title of Manuscript	References	Sector	Methods
2023	Metaverse integration alternatives of connected autonomous vehicles with self-powered sensors using fuzzy decision making model	[21]	Transportation	Fuzzy ALWAS – Fuzzy FUCOM
2024	A novel WENSLO and ALWAS multicriteria methodology and its application to green growth performance evaluation	[5]	Sustainability	WENSLO – ALWAS
2025	Ranking performance in statistics and operational research: A fuzzy MCDM and cluster-based QS 2024 framework	[22]	Education	p,q-QOFSs – K-Means – ALWAS
2025	Advantage prioritization of digital carbon footprint awareness in optimized urban mobility using fuzzy Aczel Alsina based decision making	[23]	Transportation	Fuzzy ALWAS
2026	Integrating WENSLO, Rough OPA, and ALWAS Methods for Strategic 5G Deployment: A Case Study from Turkey	[24]	Telecommunication	WENSLO – ALWAS – Rough OPA
2026	A Z-Number Fuzzy WENSLO–ALWAS Model for Evaluating Sustainable Airport Mobility and Climate-Transition Performance Using Secondary Data	[25]	Sustainability	Z-Number – Fuzzy WENSLO – Fuzzy ALWAS

An examination of Tables 2 and 3 reveals that both the MEREC and ALWAS methods have been employed as problem-solving tools across a wide variety of domains. In this study, the integration of these two methods will provide a distinct decision-making framework for the military literature.

3. Definition Problem

Given the evolving and transforming nature of the modern battlefield, military forces must address their specific requirements by integrating various capabilities into a compact structure. Consequently, this article evaluates 7 alternatives against 16 distinct criteria, focusing on the specific characteristics of wheeled amphibious vehicles. Criteria C_1 , C_2 , C_3 , and C_4 are classified as cost criteria, while the remaining criteria are categorized as benefit criteria.

3.1 Definition of the Criteria

Length (C_1): Refers to the longitudinal dimension (depth) of the amphibious vehicle.

Width (C_2): Refers to the lateral dimension (width) of the amphibious vehicle.

Height (C_3): Refers to the distance from the point of contact with the ground to the highest point of the amphibious vehicle.

Weight (C_4): Refers to the weight of the amphibious vehicle itself.

Ground Clearance (C_5): Refers to the distance between the underside of the amphibious vehicle's armor (chassis/hull) and the ground.

Engine Power (C_6): Refers to the power output of the amphibious vehicle's engine.

Cruising Range (C_7): Refers to the distance the amphibious vehicle can travel on a full fuel tank.

Speed (Maximum Road) (C_8): Refers to the maximum speed the amphibious vehicle can reach on land.

Speed (Maximum Swim) (C_9): Refers to the maximum speed the amphibious vehicle can reach while traveling in water.

Gradient (C_{10}): Refers to the maximum incline (slope) the amphibious vehicle can traverse while moving on land.

Side Slope (C_{11}): Refers to the maximum lateral incline (tilt) the amphibious vehicle can handle, such as when its wheels or tracks on one side encounter obstacles or uneven terrain.

Vertical Step (C_{12}): Refers to the maximum height of a vertical obstacle that the amphibious vehicle can surmount.

Fording Depth (C_{13}): Refers to the maximum depth of water through which the amphibious vehicle can travel.

Caliber (C_{14}): Refers to the diameter of the ammunition used by the primary weapon system of the amphibious vehicle.

Max Rate of Fire (C_{15}): The maximum number of rounds that the amphibious vehicle's main weapon can fire per minute.

Muzzle Velocity (C_{16}): The initial speed at which the ammunition used by the amphibious vehicle's main weapon exits the barrel.

The names for the alternatives have not been specified, for reasons of military security. The alternatives are designated, in order, as A_1 , A_2 , A_3 , A_4 , A_5 , A_6 , and A_7 .

4. Methodology

4.1 Definition of MEREC method

In this section, a new method known as MEREC is introduced for determining criterion weights in multi-criteria decision-making problems; this method is based on the effects that criteria exert on the final outcomes. MEREC falls under the category of objective weighting methods used to derive the

importance (weights) of various criteria. By analyzing the fundamental effects that criteria produce, the MEREC method assigns higher weights to those criteria that, when altered, lead to more significant changes in overall performance. To apply this method, one must first establish a metric for the performance of the alternatives. In this paper, a logarithmic measure assuming equal weights for all criteria is employed to calculate the performance of the alternatives. The approach relies on an absolute measure of the impact resulting from each criterion. Specifically, it captures the variation between an alternative's overall performance and its performance in a scenario where that particular criterion is excluded. The following steps are taken to determine objective weights using the MEREC method [4]:

Step 1. Construct the decision matrix. A decision matrix is constructed in this step, which shows each alternative's ratings or values concerning each criterion. The elements of this matrix are denoted by x_{ij} , and these elements should be greater than zero ($x_{ij} > 0$). If we have negative values in the decision matrix, they should be transformed into positive values using an appropriate technique. Suppose that there are n alternatives and m criteria, and the form of the decision-matrix is as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{im} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nj} & \cdots & x_{nm} \end{bmatrix} \quad (1)$$

Step 2: Normalize the decision matrix (N). In this step, a simple linear normalization is used to scale the elements of the decision-matrix. The elements of the normalized matrix are denoted by n_{ij}^x . If $\mathcal{B}$ shows the set of beneficial criteria, and $\mathcal{H}$ represents the set of non-beneficial criteria, we can utilize the following equation for normalization:

$$n_{ij}^x = \begin{cases} \frac{\min_k x_{kj}}{x_{ij}} & \text{if } j \in \mathcal{B} \\ \frac{x_{ij}}{\max_k x_{kj}} & \text{if } j \in \mathcal{H} \end{cases} \quad (2)$$

It should be noted that the normalization process is similar but different from the process used in methods like WASPAS. The difference is in switching between the formulas of beneficial and non-beneficial criteria. Unlike many other studies, we transform all the criteria into the minimization type criteria.

Step 3: Calculate the overall performance of the alternatives (S_i). A logarithmic measure with equal criteria weights is applied to obtain alternatives' overall performances in this step. This measure is based on a non-linear function depicted in Figure 1. According to the normalized values obtained from the previous step, we can ensure that smaller values of n_{ij}^x yield greater values of performances (S_i). The following equation is used for the calculation:

$$S_i = \ln \left(1 + \left(\frac{1}{m} \sum_j |\ln(n_{ij}^x)| \right) \right) \quad (3)$$

Step 4: Calculate the performance of the alternatives by removing each criterion. In this step, we use the logarithmic measure in a similar way to the previous step. The difference between this step and Step 3 is that the alternatives' performances are calculated based on removing each criterion separately. Therefore, we have m sets of performances associated with m criteria. Let us denote by S'_{ij} the overall performance of i th alternative concerning the removal of j th criterion. The following

equation is used for the calculations of this step:

$$S'_{ij} = \ln \left(1 + \left(\frac{1}{m} \sum_{k, k \neq j} |\ln(n_{ik}^x)| \right) \right) \quad (4)$$

Step 5: Compute the summation of absolute deviations. In this step, we calculate the removal effect of the j th criterion based on the values obtained from Step 3 and Step 4. Let E_j denote the effect of removing j th criterion. We can calculate the values of E_j using the following formula:

$$E_j = \sum_i |S'_{ij} - S_i| \quad (5)$$

Step 6: Determine the final weights of the criteria. In this step, each criterion's objective weight is calculated using the removal effects (E_j) of Step 5. In what follows, w_j stands for the weight of the j th criterion. The following equation is used for the calculation of w_j :

$$w_j = \frac{E_j}{\sum_k E_k} \quad (6)$$

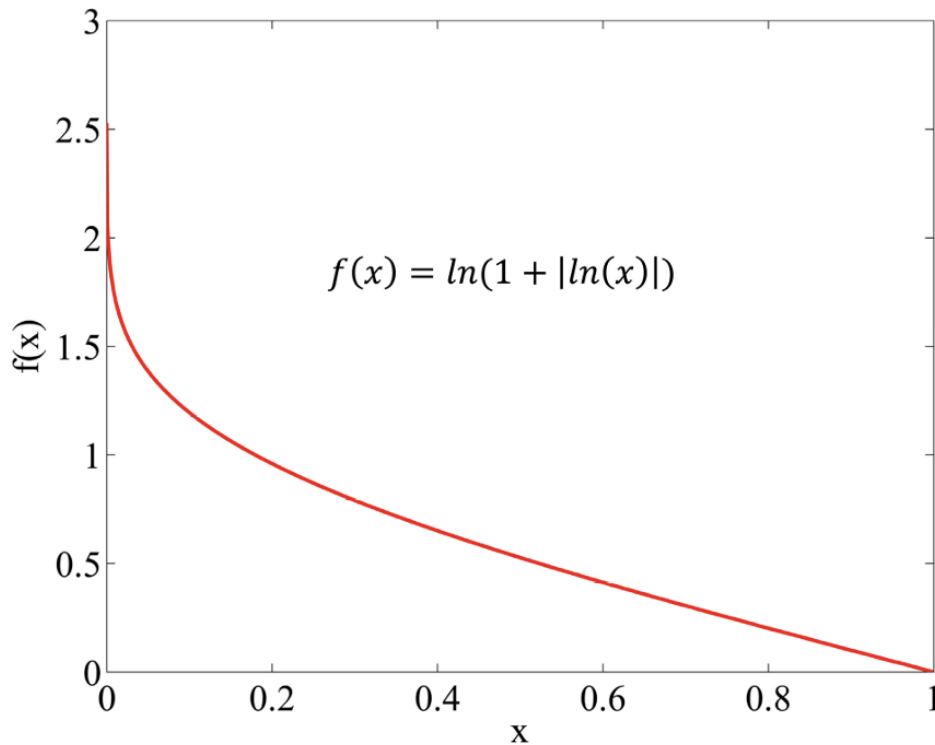


Fig. 1. The weights of the comparative analysis [4]

4.2 Definition of ALWAS Method

The ALWAS method is based on the application of Aczel-Alsina nonlinear functions, which are used to define weighted alternative strategies. These weighted strategies are employed to determine the preliminary impact of the alternatives and to establish the outcome evaluation scores for these alternatives. The following section outlines the methodological procedure of the ALWAS technique, which consists of four steps [5]:

Step 1: Matrix generation: Suppose that an evaluation of m alternatives A_i ($i = 1, 2, \dots, m$) under n criteria C_j ($j = 1, 2, \dots, n$) was performed. Then, we can form a matrix $\mathfrak{R} = [\zeta_{ij}]_{m \times n}$, where ζ_{ij} represents an estimated i th alternative under the j th criterion; $i = 1, \dots, m$; $j = 1, \dots, n$:

Step 2: Matrix standardization: Since the criteria presented in different units of measurement were used to evaluate the alternatives, it is necessary to standardize the information in the matrix

$\mathfrak{R} = [\zeta_{ij}]_{m \times n}$. Standardization of information implies translating all elements ζ_{ij} into the interval between zero and one, i.e., $\zeta_{ij} \in [0, 1]$. The standardization of the matrix was performed using, which defined the standardized matrix $\mathfrak{R}^s = [\hat{\zeta}_{ij}]_{m \times n}$.

$$\hat{\zeta}_{ij} = \begin{cases} \hat{\zeta}_{ij} = \frac{\zeta_{ij}}{\zeta_j}, & \text{if } j \in B \\ \hat{\zeta}_{ij} = -\frac{\zeta_{ij}}{\zeta_j} + \max_{1 \leq i \leq m} \left(\frac{\zeta_{ij}}{\zeta_j} \right) + \min_{1 \leq i \leq m} \left(\frac{\zeta_{ij}}{\zeta_j} \right), & \text{if } j \in C \end{cases} \quad \text{where } \zeta_j = \max_{1 \leq i \leq m} (\zeta_{ij}) \quad (7)$$

Step 3. Defining the weighted strategies for combining alternatives: Based on Aczel–Alsina norms, we can define weighted nonlinear functions based on Aczel–Alsina norms. Aczel–Alsina nonlinear functions are used to describe final strategies for combining alternatives. In the following section, two weighted strategies for integrating alternatives are defined.

1) Aczel–Alsina weighted averaging strategy ($\mathbb{R}_i^{(1)\xi}, i = 1, \dots, m$).

Theorem 1: Let $\hat{\zeta}_{ij}$ ($i = 1, 2, \dots, m; j = 1, 2, \dots, n$) be a set of elements of the matrix $\mathfrak{R}^s = [\hat{\zeta}_{ij}]_{m \times n}$ and let $w_j = (w_1, w_2, \dots, w_n)^T$ be the vector of weight coefficients of the criteria, then, by applying, we can define the Aczel–Alsina averaging strategy of association ($\mathbb{R}_i^{(1)\xi}$)

$$\mathbb{R}_i^{(1)\xi} = \sum_{j=1}^n \hat{\zeta}_{ij} \left(1 - e^{-\left(\sum_{j=1}^n w_j (-\ln(1 - f(\hat{\zeta}_{ij})))^\xi \right)^{\frac{1}{\xi}}} \right) \quad (8)$$

where $f(\hat{\zeta}_{ij}) = \hat{\zeta}_{ij} / \sum_{j=1}^n \hat{\zeta}_{ij}$ and $\xi \geq 0$. Then $\mathbb{R}_i^{(1)\xi}$ represents the Aczel–Alsina weighted averaging strategy.

2) Aczel–Alsina weighted geometric averaging strategy ($\mathbb{R}_i^{(2)\xi}, i = 1, \dots, m$).

Theorem 2: Let $\hat{\zeta}_{ij}$ ($i = 1, 2, \dots, m; j = 1, 2, \dots, n$) be a set of elements of the matrix $\mathfrak{R}^s = [\hat{\zeta}_{ij}]_{m \times n}$ and let $w_j = (w_1, w_2, \dots, w_n)^T$ be the vector of weight coefficients of the criteria, then the Aczel–Alsina weighted geometric averaging strategy of association ($\mathbb{R}_i^{(2)\xi}$) can be represented as follows:

$$\mathbb{R}_i^{(2)\xi} = \sum_{j=1}^n \hat{\zeta}_{ij} \cdot e^{-\left(\sum_{j=1}^n w_j (-\ln(f(\hat{\zeta}_{ij})))^\xi \right)^{1/\xi}} \quad (9)$$

where $f(\hat{\zeta}_{ij}) = \hat{\zeta}_{ij} / \sum_{j=1}^n \hat{\zeta}_{ij}$ and $\xi \geq 0$. Then $\mathbb{R}_i^{(2)\xi}$ represents the Aczel–Alsina weighted geometric averaging strategy.

Step 4: Calculation of integrated weighted alternative strategies ($\mathfrak{S}_i$): The integration of weighted strategies for aggregation and was performed as follows:

$$\mathfrak{S}_i = \frac{\mathbb{R}_i^{(1)\xi} + \mathbb{R}_i^{(2)\xi}}{1 + \left\{ \varphi \left(\frac{1 - f(\mathbb{R}_i^{(1)\xi})}{f(\mathbb{R}_i^{(1)\xi})} \right)^\theta + (1 - \varphi) \left(\frac{1 - f(\mathbb{R}_i^{(2)\xi})}{f(\mathbb{R}_i^{(2)\xi})} \right)^\theta \right\}^{1/\theta}} \quad (10)$$

where $\theta > 0, \varphi \geq 0$, $f(\mathbb{R}_i^{(1)\xi}) = \mathbb{R}_i^{(1)\xi} / \mathbb{R}_i^{(1)\xi} + \mathbb{R}_i^{(2)\xi}$, and $f(\mathbb{R}_i^{(2)\xi}) = \mathbb{R}_i^{(2)\xi} / \mathbb{R}_i^{(1)\xi} + \mathbb{R}_i^{(2)\xi}$.

The ranking of alternatives is done based on integrated weighted strategies of alternatives ($\mathbb{S}_i$), where the alternative with a higher value $\mathbb{S}_i$ has a better ranking.

5. Results

5.1 Results of MEREC method

To normalize the decision matrix, it is necessary to determine the maximum and minimum values for each criterion, as indicated in Table 4. The dataset provided in Table 4 should be used to construct the decision matrix. The decision matrix, which includes information regarding the nature of the criteria, is presented in Table 5.

Table 4

The decision matrix

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀	C ₁₁	C ₁₂	C ₁₃	C ₁₄	C ₁₅	C ₁₆
A ₁	7.65	2.95	2.8	14550	0.475	240	600	90	10	60	40	0.5	2	30	330	1120
A ₂	6.393	2.499	2.692	12792	0.378	275	668	100	9.66	60	30	0.5	2	25	200	1345
A ₃	6.93	2.66	2.15	18500	0.57	400	600	100	10	60	30	0.5	1.5	25	500	1345
A ₄	8.1	2.8	2.4	32000	0.4	612	1000	100	10	60	30	0.7	1.8	30	350	1480
A ₅	6.35	2.7	2.3	22000	0.45	410	800	120	8	60	30	1	2	40	375	240
A ₆	6.53	2.62	2.69	13200	0.378	275	660	100	10	60	30	0.5	2	25	500	1100
A ₇	8.4	3.1	2.5	30000	0.55	711	600	100	5	60	30	0.7	1.5	25	200	1345
Max	8.4	3.1	2.8	32000	0.57	711	1000	120	10	60	40	1	2	40	500	1480
Min	6.35	2.499	2.15	12792	0.378	240	600	90	5	60	30	0.5	1.5	25	200	240

The overall performance value of the alternatives is calculated using Equation 3.

Table 5

The normalized decision matrix

	C	C	C	C	B	B	B	B	B	B	B	B	B	B	B	B
	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀	C ₁₁	C ₁₂	C ₁₃	C ₁₄	C ₁₅	C ₁₆
A ₁	0.83	0.85	0.77	0.88	0.83	0.34	0.60	0.75	1.00	1.00	1.00	0.50	1.00	0.75	0.66	0.76
A ₂	0.99	1.00	0.80	1.00	0.66	0.39	0.67	0.83	0.97	1.00	0.75	0.50	1.00	0.63	0.40	0.91
A ₃	0.92	0.94	1.00	0.69	1.00	0.56	0.60	0.83	1.00	1.00	0.75	0.50	0.75	0.63	1.00	0.91
A ₄	0.78	0.89	0.90	0.40	0.70	0.86	1.00	0.83	1.00	1.00	0.75	0.70	0.90	0.75	0.70	1.00
A ₅	1.00	0.93	0.93	0.58	0.79	0.58	0.80	1.00	0.80	1.00	0.75	1.00	1.00	1.00	0.75	0.16
A ₆	0.97	0.95	0.80	0.97	0.66	0.39	0.66	0.83	1.00	1.00	0.75	0.50	1.00	0.63	1.00	0.74
A ₇	0.76	0.81	0.86	0.43	0.96	1.00	0.60	0.83	0.50	1.00	0.75	0.70	0.75	0.63	0.40	0.91

With the removal of each criterion, the performance values of the alternatives are calculated using Equation 4. The resulting values are presented in Table 6.

The weight of each criterion is determined using Equation 6. The resulting values are presented in Figure 2.

Figure 2 presents the distribution of weight coefficients for 16 distinct criteria, determined using the MEREC method, in the form of a bar chart. An examination of these coefficients reveals that the "Vertical Step" criterion holds the highest level of importance compared to the others. The "vertical step" refers to the maximum height of a vertical wall or obstacle that an amphibious or military vehicle can surmount either while in motion or by climbing it at a steep angle. In the context of amphibious vehicles, the weight criterion is also of critical importance, as it influences the vehicle's potential to slow down during land operations, thereby increasing the likelihood of detection and

targeting by an adversary. Overall, there is no single dominant criterion; rather, the weight coefficients are relatively close to one another, reflecting a balanced distribution.

Table 6

Performance values of the alternatives calculated by removing each criterion

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀	C ₁₁	C ₁₂	C ₁₃	C ₁₄	C ₁₅	C ₁₆
A ₁	0.91	0.78	0.95	0.94	0.77	0.81	0.96	0.95	0.76	0.77	0.93	0.97	0.76	0.78	0.96	0.95
A ₂	0.78	0.60	0.91	0.93	0.95	0.64	0.92	0.94	0.93	0.60	0.92	0.97	0.93	0.62	0.94	0.94
A ₃	0.82	0.94	0.93	0.70	0.85	0.96	0.96	0.69	0.85	0.93	0.95	0.72	0.87	0.96	0.93	0.69
A ₄	0.82	0.64	0.94	0.87	0.74	0.64	0.93	0.84	0.72	0.64	0.95	0.85	0.72	0.65	0.95	0.83
A ₅	0.82	0.73	0.74	0.96	0.95	0.75	0.75	0.93	0.95	0.72	0.75	0.93	0.93	0.72	0.75	0.99
A ₆	0.80	0.60	0.95	0.94	0.93	0.64	0.96	0.94	0.91	0.60	0.95	0.97	0.91	0.62	0.93	0.95
A ₇	0.74	0.91	0.44	0.72	0.69	0.90	0.46	0.69	0.72	0.90	0.45	0.70	0.71	0.92	0.47	0.69

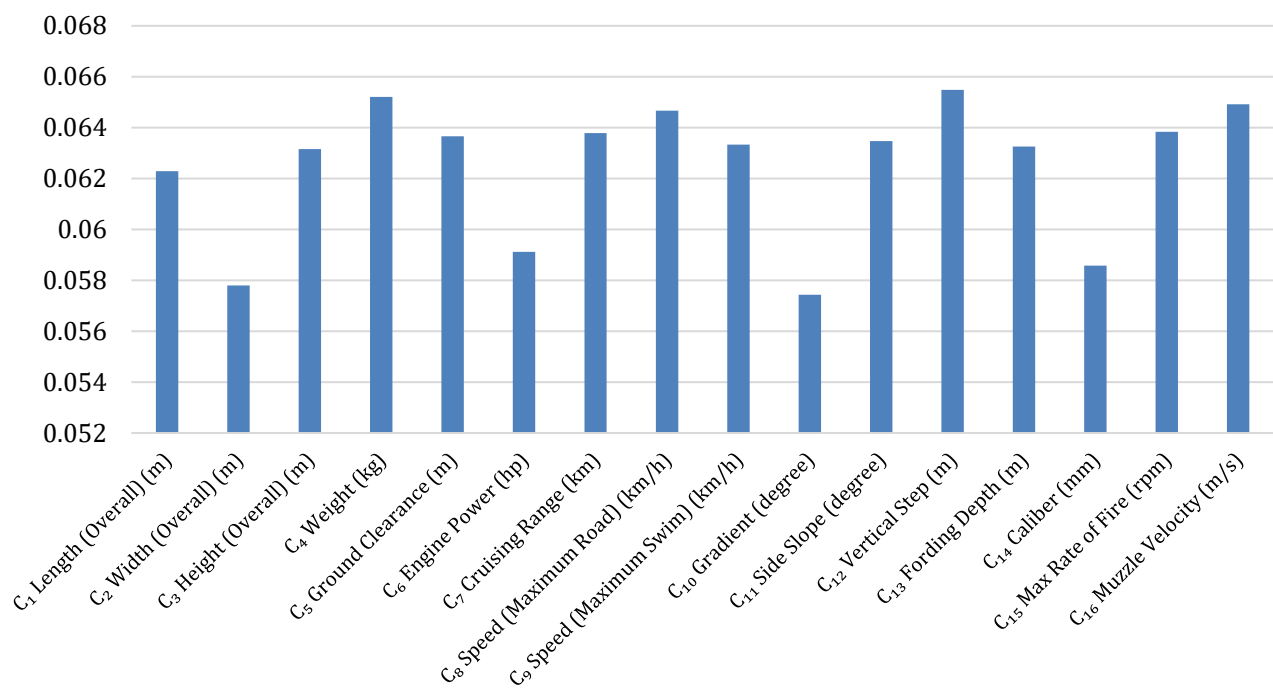


Fig. 2. Weight of Criteria

5.2 Results of ALWAS method

The decision matrix has been standardized using the equations in Equation (7). Weighted strategies for aggregating alternatives were calculated using Equations (8) and (9). In this step, the necessary criterion weights were determined via the MEREC method. The resulting weights are presented in Figure 2. In the final step, the integrated weighted alternative strategies were calculated using Equation (5). For these calculations, the parameters were set as follows: $\xi = 1$, $\Gamma = 0.5$, and $\phi = 1$. All results are presented in Table 7.

The results for A₁, presented in the first row of Table 7, were obtained as follows. The values $\mathbb{R}_1^{(1)\xi=1}$ and $\mathbb{R}_1^{(2)\xi=1}$ were calculated using Equation (8) and Equation (9). With the final step, the integrated weighted alternative strategies were calculated using Equation (10).

Based on the obtained H_i values, the ranking of the alternatives in terms of their environmental sustainability performance is $A_3 > A_4 > A_5 > A_6 > A_1 > A_2 > A_7$.

Table 7

Results for the ALWAS method

	R1	R2	R1+R2	f(R1)	f(R2)				Result	Rank
A ₁	0.789	0.760	1.549	0.509	0.491	0.482	0.519	2.001	0.774	5
A ₂	0.783	0.747	1.530	0.512	0.488	0.477	0.524	2.001	0.764	6
A ₃	0.828	0.807	1.635	0.506	0.494	0.488	0.513	2.000	0.817	1
A ₄	0.824	0.805	1.629	0.506	0.494	0.488	0.512	2.000	0.814	2
A ₅	0.826	0.771	1.597	0.517	0.483	0.467	0.536	2.002	0.797	3
A ₆	0.807	0.780	1.587	0.509	0.491	0.483	0.518	2.001	0.793	4
A ₇	0.745	0.719	1.465	0.509	0.491	0.483	0.518	2.001	0.732	7

6. Sensitivity Analyses

In this section, the mathematical validity of the methodology and the results is examined through sensitivity analyses. The first sensitivity analysis was conducted for ALWAS with respect to the stabilization parameter. The literature advises against using high values for the stabilization parameter, ξ ; instead, it is recommended to consider values within the range $1 \leq \xi \leq 5$ [5]. Based on the analysis performed, alternative A₃ remained in the top position for all values of ξ . The results of this parameter analysis are presented in Figure 3.

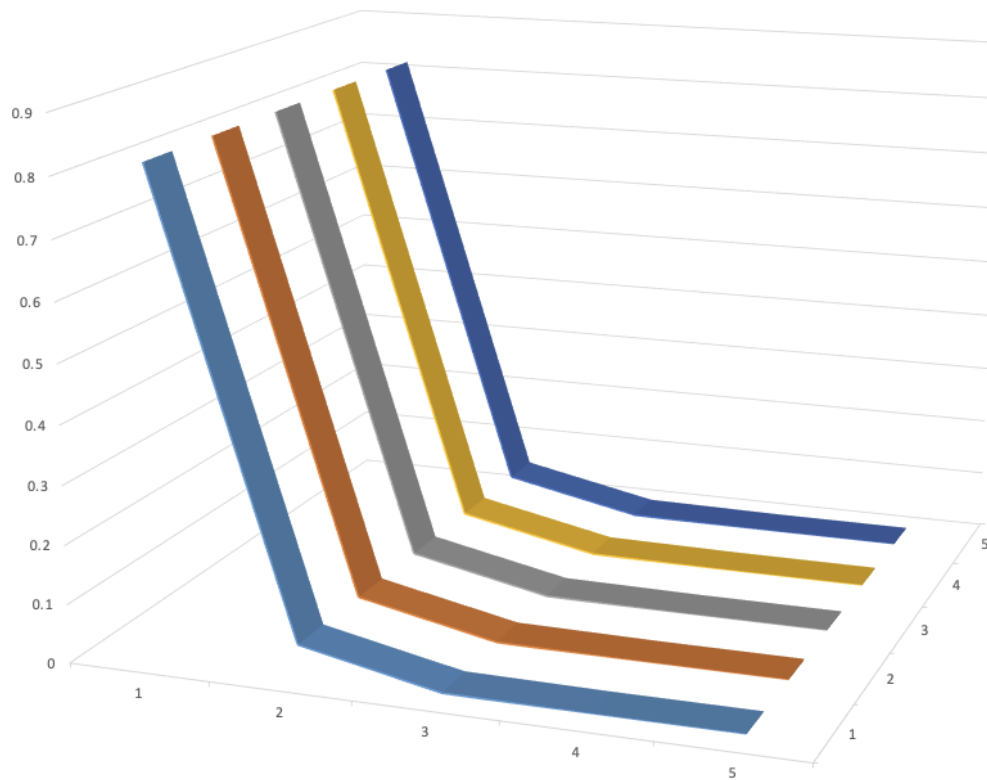


Fig. 3. Changes in the Aczel-Alsa function of alternative A3 during the change of the parameter $1 \leq \xi \leq 5$

The ϕ and θ parameters represent the stabilization functions that integrate weighted alternative strategies. The values $\phi = 0.5$ and $\theta = 1$ were introduced to calculate the initial solution. In the following part, a simulation of the change of the mentioned parameters was performed through two phases. In the first phase, the change of the parameter $0 \leq \phi \leq 1$ was simulated. Figure 4 shows the influence of parameter $0 \leq \phi \leq 1$ on changes in the criterion functions of alternatives.

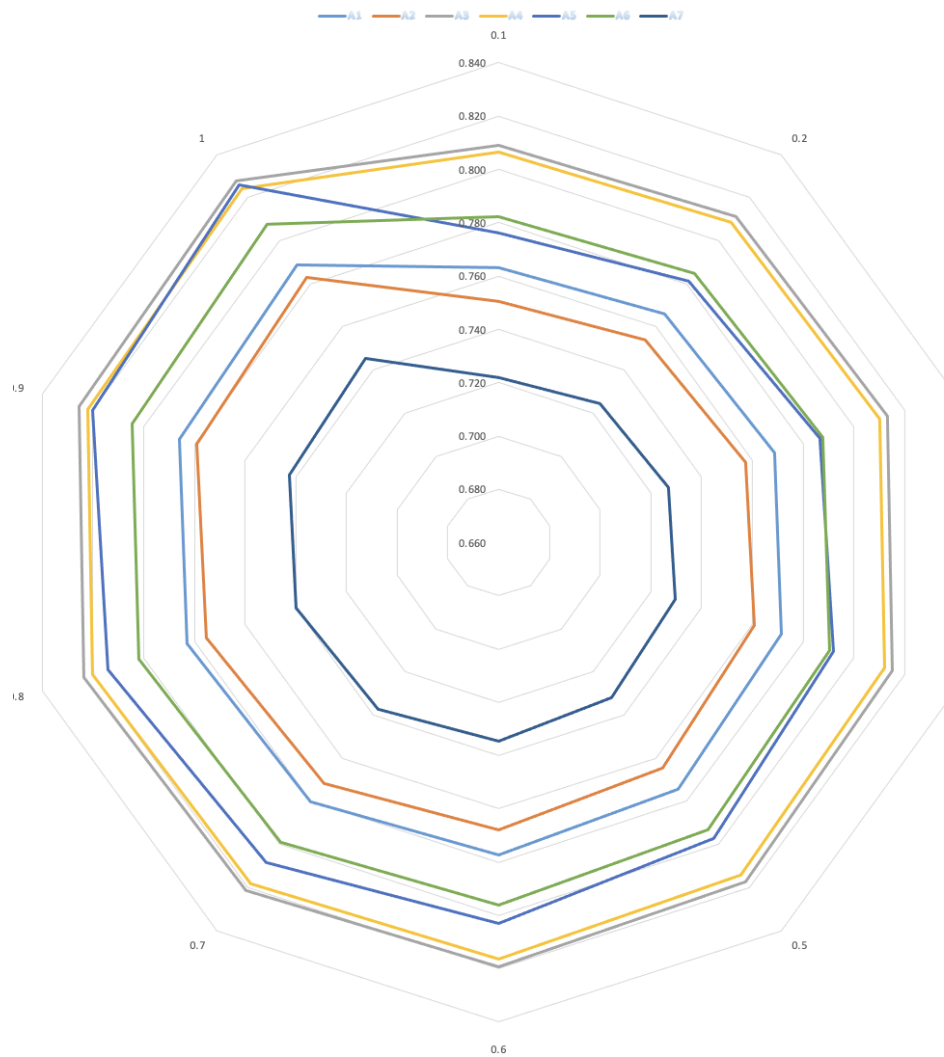


Fig. 4. Influence of parameter ϕ on change of initial results

An examination of Figure 4 reveals that the top-ranked alternative remains the same across all scenarios. In most scenarios, the positions of the other alternatives also remain unchanged. There are only minor shifts in the rankings of the alternatives occupying the second, third, and fourth positions.

7. Conclusions

MCDM methods are widely used in the literature to address various critical decision-making problems. In this study, two contemporary MCDM methods have been integrated in an innovative manner to provide a solution to a military decision-making problem. Given the significant difficulty in obtaining objective data for such decision-making scenarios, the study relies on data gathered from open-source information [26]. Based on the decision matrix derived from this data, criterion weights were determined using the MEREC method, while the ranking of alternatives was established through the ALWAS method. The resulting outcomes were subjected to sensitivity analyses using various parametric assessments.

The findings clearly demonstrate that the MEREC-ALWAS methodology serves as a robust tool for rational and objective decision-making processes. Nevertheless, alongside its distinct advantages, this study also presents certain limitations. One such limitation is that the uncertainty inherent in the data used to evaluate the alternatives has not been accounted for. Consequently, future research

aims to address these uncertainties within the core matrix of the MCDM model by incorporating fuzzy logic, in alignment with existing literature. Furthermore, it would be beneficial for future studies to explore the integration of the MEREC and ALWAS methods with other MCDM techniques.

Acknowledgement

This research was not funded by any grant.

Conflicts of Interest

The authors declare no conflicts of interest.

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