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# Selection of Military Armored Vehicle Using Fuzzy EDAS method

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**ABSTRACT**

Military armored vehicles are specially designed and equipped for defense and security activities. During military operations, the right vehicle selection is of vital importance for the success of the operation. This problem examined 5 different alternative military armored vehicles for operational and logistic success using the criteria Engine Power, Dimensions, Fire Power Range, Gradeability, and Armor Thickness. In military decision problems, some alternatives probably need to be evaluated regarding more than one conflicting criterion. The decision among these alternatives will usually involve other strategic-level decisions. Multi-criteria decision-making (MCDM) refers to making decisions in such a situation. Are there any methods and techniques available to solve MCDM problems? The evaluation according to distance from average solution (EDAS) method is a multi-criteria decision-making method whose effectiveness has been tested in other problem areas in the literature. In this study, we use the EDAS method to address the problem of military armored vehicle selection in a fuzzy environment. While a Type-1 fuzzy set is used in the fuzzy EDAS method, trapezoidal fuzzy numbers are preferred for military expert evaluation. The results of this study show that the fuzzy EDAS method is effective.

## 1. Introduction

Work on the first armored personnel carriers that could transport infantry under armor protection began in coordination with tanks during the First World War. During the Second World War, Germany established panzergrenadier (mechanized infantry) units to provide the necessary infantry support for the advance of the panzers. This new class entered the battle primarily in SdKfz 251 half-track vehicles that accompanied tanks, thus adding armor protection, flexibility, and speed to infantry combat. Progressive developments have included the armored vehicle accompanying tanks, which have a design that can involve infantry in combat in a completely closed compartment and are armed at a level that can provide high fire support. In addition to increasing terrain capability and firepower, armored vehicles can be used by infantry to limit protection against heavy weapons, ease adaptation to changing tactical situations, and hurt enemy morale.

When the Cold War ended, spending on defense decreased rapidly all over the world, but especially in Europe. As a result, while armies were shrinking, army structures based on armored

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units of the Cold War period also entered a process of change. The number of tanks, armored personnel carriers, and armored combat vehicles decreased rapidly. Because of the threat posed by the huge land forces, the armies of the Soviet Union, consisting of armored and motorized divisions, had now disappeared. Instead, new multidimensional threats in the new multipolar world began to be talked about, and they also found a place in NATO threat assessments. These threats were accepted to be caused by failed states, terrorist organizations, international criminal organizations, radicalism, ethnic and religious conflicts, and other non-state actors. For this reason, new doctrines and concepts were developed according to new threats. When the threats became so diverse, conflicts naturally increased rapidly compared to the Cold War period. These conflicts were mostly low-intensity. These conflicts and operations were given various names, such as peacekeeping, peace enforcement, democratization, humanitarian aid, counterterrorism, and even the war on terror. Most of these struggles took place in residential areas.

These battles in residential areas revealed the inadequacies and shortcomings of the existing weapons and vehicles, organizational structures, doctrines, and concepts manufactured and used according to the conventional war approach of the bipolar world. The world's armies began to innovate their personnel and organizational structures, training, equipment, doctrines, weapons, and vehicles. Those most affected by this change were armored units. Because it was seen that caterpillar armored vehicles were not suitable for combat in residential areas. First, when pallets were used on asphalt roads and in the city, they damaged the roads and infrastructure. The hard ground and sharply cornered shoulders were damaging the pallets. As failure rates increased accordingly, it began to be thought that these vehicles, especially armored personnel carriers, could not be used effectively and efficiently. On the other hand, these armored vehicles, which were quite wide and high, were a major target in the streets and avenues. The size of the vehicles made them difficult to maneuver and turn. For these reasons, smaller vehicles with rubber wheels that can carry more personnel, consume less fuel, have less maintenance costs, have greater protection against explosives, and have greater armor thickness have begun to be produced.

In addition to the duties of the residential area, the geography where the operation is carried out is an important factor in vehicle selection. Since geographical features affect the mobility and performance of vehicles, appropriate vehicle selection should be made by considering the operation's geographical features [1]. For example, heavy armored vehicles may be preferred for an open and flat geography. However, lighter and more maneuverable vehicles may suit a mountainous geography. Likewise, vehicles with trench-crossing features will be more suitable for operational areas with wide ditches and obstacles.

Military land vehicles are specially designed and equipped with armor for defense and security purposes. They can be used not only to provide security and protection during military operations but also for other civilian law enforcement purposes [2]. Military armored land vehicles have various designs and features and are designed for different missions [3]. In terms of operational and logistical success, it is necessary to evaluate the features of the vehicles correctly and pay attention to the operation details and vehicle features when selecting the vehicle.

Especially the war between Russia and Ukraine in recent years has accelerated this new trend. The world has seen that conventional warfare, and therefore armored units, have not become obsolete; they have only changed shape. As seen in Ukraine, battles today occur mostly in residential areas. These battles have shown us that despite the lethal effects of UAVs and new-generation anti-tank weapons, tanks and armored vehicles are still important in winning wars. Due to the impact of the Russia-Ukraine war, there was a huge increase in armored vehicle expenditures globally. Instead of the costly and high-profile main battle tank and tracked armored personnel carrier/armored combat vehicle production and procurement programs, the real notable increase was in wheeled armored vehicles. This is so much so that, according to the market report of Defense Insight, which is published in the field of defense, it is estimated that a worldwide expenditure of 25.6 billion dollars will be made on rubber-tired armored vehicle programs from 2022 to 2035. Wheeled armored vehicles, which were initially used mainly for the rapid movement of soldiers behind the lines, became an indispensable weapon system of war in the following years as their off-road capabilities increased thanks to the development of tire, engine, and suspension technology.

The market for wheeled armored combat vehicles in the light and medium weight class is growing faster. Because the frequency and requirements of today's asymmetric battles do not comply with the operational concept of heavy armored units, we see that armor protection is increasing in wheeled vehicles, which are threatened by easy-to-access (IED, RPG, mine, etc.) and cheap weapons. In parallel with increasing armor protection, the diameter and diversity of weapons also increase.

Considering the role of armored vehicles in wars and this high market, the issue of which one to choose among various armored vehicles emerges as an important decision problem. It is of great importance for the defense industry of the countries to tackle the issue of choosing an appropriate vehicle, among many, with a wide range of criteria such as performance, protection levels, weapon systems, ease of maintenance, cost advantage, carrying capacity, and improved strategic mobility.

In this study, the analysis of selecting between 5 different types of vehicles in similar classes, using the Fuzzy Evaluation based on the Distance from Average Solution (EDAS) method, has been presented. In the second part of the study, there is a literature review; in the third part, information about the weapon system; in the fourth part, the methodology of the study; in the fifth part, a sample application; and in the last part, conclusion evaluations. As a result of this analysis, it will be determined which military armored land vehicles are most suitable and will help decision-makers make a more effective choice.

## 2. Literature Review

In decision problems, experts can find the criteria weights by using any multi-criteria decision-making (MCDM) technique and stating their preferences for the targets. They then rank these criteria according to their importance and are significantly influenced by this ranking in deciding which alternative to choose. As an alternative to existing MCDM methods, Ghorabaee et al. (2015) developed the EDAS method [4]. Although it has been proposed more recently than many other methods, it is frequently used for different application areas [5-10]. The fuzzy logic approach is used when the nature of MCDM problems, especially military decision problems, is uncertain or in the digitization of linguistic expressions [11,12]. This approach is an important alternative solution for military decision problems when deterministic solutions cannot be reached through operations research [13-15]. For this reason, some prominent studies in the Fuzzy EDAS literature are shared in Table 1.

When Table 1 is examined, it can be seen that the EDAS method is used integrated with many different fuzzy sets such as q-rung orthopair, intuitionistic, neutrosophic, interval-valued neutrosophic, Type-1, Interval Type-2 and Image blurred, and solutions are achieved in many different application areas.

**Table 1**. Literature on Fuzzy EDAS Method

| References | Application | Method |
|---|---|---|
| [16] | Defense Industry Supplier Selection | q-ROFS EDAS |
| [17] | Renewable Energy | intuitionistic-fuzzy EDAS |
| [18] | Site Selection of Medical Waste | interval-valued neutrosophic fuzzy EDAS |
| [19] | Aviation Industry | Neutrosophic Fuzzy EDAS |
| [20] | Solid Waste Disposal Facility Location Selection | intuitionistic-fuzzy EDAS |
| [21] | Supplier Selection | interval type-2 Fuzzy EDAS |
| [22] | Personnel selection | Type 1 Fuzzy EDAS |
| [23] | Supplier Selection | Type 1 Fuzzy EDAS |
| [24] | Hydrogen Mobility Collection Facility Location Selection | intuitionistic-fuzzy EDAS |
| [25] | Supplier Selection | Picture fuzzy EDAS |
| [26] | Autonomous Maintenance System | Type 1 Fuzzy EDAS |
| [27] | Project Selection for Sustainable And Green Buildings | intuitionistic-fuzzy EDAS |
| [28] | Passenger Railway Operator Strategy Selection | Type 1 Fuzzy EDAS |
| [29] | Healthcare Sector Waste Disposal Technology Selection | intuitionistic-fuzzy EDAS |

## 3. Armored Vehicle Selection

Military vehicles have been used for centuries to meet armies' maneuver and defense needs. These vehicles provide armored protection to their personnel and significantly contribute to the maneuverability and firepower of the troops. These vehicles, which vary according to the battlefield and scope of activity, have been forced to compete against weapons that have developed over time and have produced new armored vehicles with higher technology [30,31]. In general terms, armored personnel carriers are vehicles used to bring infantrymen under armor protection closer to the line of fire as quickly as possible. The system is expected to be adequately armored against light weapons and shrapnel, have high terrain capability, and have a low silhouette.

Armored vehicles are used for various military purposes. These vehicles, designed for different missions, such as defensive and offensive missions during combat, are also classified according to their light, medium, and heavy armor features. Light armored vehicles have low weight and armor thickness and are usually equipped with light artillery and machine guns. Medium-class armored vehicles have heavier armor thickness and are equipped with cannons and machine guns. Heavy-class armored vehicles have the heaviest armor thickness and are equipped with heavy artillery weapons [32,33].

To realize military activities and strategic goals, personnel, soldiers, and logistics materials working on the battlefield must be transported. Speed and carrying capacity are among the important features of armored vehicles designed for these purposes. These vehicles have wheeled and tracked options depending on war conditions and can also have amphibious features. As armor, it protects against artillery attacks and infantry weapons, while the protection rate can be increased according to needs [34]. Regarding firepower, light but effective 12.7 mm and 7.62 mm machine guns or 40 mm automatic grenade launchers are generally preferred.
We see that armor protection is increasing in wheeled vehicles, which are threatened by easy-to-access and cheap weapons such as IEDs, RPGs, mines, etc. In parallel with the increased armor protection, we see that the diameter and diversity of weapons also increase.

Saving a little firepower provides significant carrying capacity and maneuverability advantages. These vehicles can also be used for various purposes, such as providing medical aid and supporting logistical operations. Sacrificing the amphibious feature, heavily armored personnel carriers have also become popular in some countries. With this, it is clear that a force that can actively protect itself, penetrate enemy lines alongside infantry and fire support elements under heavy enemy fire, and possess active protection systems, panoramic external viewing systems, and network-centric warfare capabilities is desired.

To achieve objectives on the battlefield, forces must be fast and flexible. Military vehicles and equipment provide operational convenience by assisting units in quickly adapting to changing conditions. Operational performance is a concept that measures how effective a vehicle or system is in a specific mission. Logistics performance, on the other hand, is a concept that measures how effectively a vehicle or system performs processes such as production, distribution, maintenance, or repair in a specific mission [35]. The operational and logistical performances of military land vehicles can vary depending on the characteristics of the vehicles and the geography where the operation is conducted.

Open-terrain operations are carried out in unobstructed areas such as open plains, deserts, or agricultural fields. In open-terrain operations where regular armies have an advantage, mobility and rapid maneuvers are generally emphasized. Personnel and vehicles are spread over a large area and have greater mobility. Considering the potential for exposure as open targets, the armor of positions and vehicles becomes important, emphasizing speed [36].

Residential operations are carried out in areas with dense human populations, such as urban areas. They are conducted to seize buildings and streets where enemy forces are located. In such operations, the narrow streets, building locations, and numerous obstacles limit the mobility of vehicles. The level of protection of armored vehicles, maneuverability, vehicle size, ability to overcome ditches and bypass barricades, and weapon systems become crucial in these operations [37].

Operations in mountainous areas are among the most challenging, requiring difficult conditions and high levels of experience and knowledge. These operations involve combatting enemy forces and dealing with high altitudes, cold weather, and rugged terrain. Mountainous terrain encompasses various features such as narrow passes, wide valleys, caves, and riverbeds [38]. Vehicles with high obstacle-crossing and incline mobility capabilities are preferred in such operations. Additionally, these vehicles' heating capability is crucial [39].

Parallel to the acceptance of large armored units as the main combat force during the Cold War, wheeled armored vehicles were given more importance. However, with the emergence of rapid intervention in the 1990s, there was a significant increase in investment in wheeled armored vehicles. The shift of combat areas to urban areas, decreased low-intensity conflicts, and expanded highway networks have led to a broader use of wheeled armored vehicles within military doctrines. Due to reasons such as lower friction and weight advantage, wheels provide lower fuel consumption than tracks. For this reason, the fact that it is possible to operate at a longer range with the same amount of fuel is an important factor in why countries sending soldiers to peacekeeping operations are turning to wheeled armored vehicles. In addition, developments in wheel technologies have made these vehicles popular. Tires that do not leak air even if punctured, and the ability of the vehicle to continue driving for a long time even if it bursts, are some examples of these. However, the main factor underlying the shift towards wheeled systems was costs. Compared to pallets, the production and maintenance costs of wheeled armored vehicles are nearly half lower. The economic reason behind this lies in the intense use of commercial automotive parts in armored vehicles. On the other hand, another important factor in the acceleration of efforts to develop wheeled armored vehicles is the shrinking defense budgets.

For the reasons explained above, there are many factors that affect the use of wheeled armored vehicles in conflict environments. Determining the weights of these criteria, which are important in the selection of these vehicles, and making the selection accordingly is of great importance in terms of cost effectiveness.

## 4. Methodology

Since uncertainty is often an inevitable part of MCDM problems, fuzzy MCDM methods are used as a useful tool for dealing with real-world decision-making problems. In this section, the extended EDAS method with Type-1 fuzzy sets is explained using trapezoidal fuzzy numbers. In this regard, firstly the trapezoidal fuzzy number is defined and the algebraic operations used in the application of the Fuzzy EDAS method are given below [40].

The trapezoidal fuzzy number μ(x) is given in Equation (1), where A is a fuzzy set, x E A and u(x) is the membership function of the fuzzy number x.

$$\mu(x) = \begin{cases} \frac{(x-a)}{(b-a)}, & a \le x < b \\ 1, & b \le x \le c \\ \frac{(d-x)}{(d-c)} & c < x \le d \\ 0, & diğer\ durumlar \end{cases} \quad (1)$$

A = (a1, a2, a3, a4) and B = (b1, b2, b3, b4) are two trapezoidal fuzzy numbers (a1 ≥ and b1 > ), and k is a crisp number. The basic algebraic operations on trapezoidal fuzzy numbers are defined as follows [40]:

- Addition: $\tilde{A} + \tilde{B} = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4)$ (2)
  $\tilde{A} + k = (a_1 + k, a_2 + k, a_3 + k, a_4 + k)$ (3)

- Subtraction: $\tilde{A} - \tilde{B} = (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1)$ (4)
  $\tilde{A} - k = (a_1 - k, a_2 - k, a_3 - k, a_4 - k)$
  (5)
- Multiplication: $\tilde{A} \times \tilde{B} = (a_1\, x\, b_1, a_2\, x\, b_2, a_3\, x\, b_3, a_4\, x\, b_4)$ (6)

$$\tilde{A} \times k \begin{cases} (a_1\, x\, k, a_2\, x\, k, a_3\, x\, k, a_4\, x\, k) & eğer\ k \ge 0 \\ (a_4\, x\, k, a_3\, x\, k, a_2\, x\, k, a_1\, x\, k) & eğer\ k < 0 \end{cases} \quad (7)$$

- Division: $\tilde{A} / \tilde{B} = (a_1 / b_4, a_2 / b_3, a_3 / b_2, a_4 / b_1)$ (8)

$$\tilde{A} / k \begin{cases} (a_1\, x\, k, a_2\, x\, k, a_3\, x\, k, a_4\, x\, k) & eğer\ k > 0 \\ (a_4\, x\, k, a_3\, x\, k, a_2\, x\, k, a_1\, x\, k) & eğer\ k < 0 \end{cases} \quad (9)$$

K = $\{K_1, K_2, \dots, K_m\}$ (i = 1,..., m) is a set of m criteria, A = $\{A_1, A_2, \dots, A_n\}$ (j = 1,...,n) is a set of n alternatives and KV = $\{KV_1, KV_2, \dots, KV_k\}$ (p =1,..., k) is a set of k decision makers . The steps of the fuzzy EDAS method can be summarized as follows [40]:

**Step 1.** Creation of a combined decision matrix for alternatives.

The decision matrices containing the performance values of the alternatives are combined by the decision makers to create the combined decision matrix given in Equation (10).

X = $[\tilde{x}_{ij}]_{nxm}$ (10)

$X_{ij} = \frac{1}{k} +_{p=1}^{k} \tilde{x}_{ij}^{p}$ (11)

In the equation above, $\tilde{x}_{ij}^{p}$ represents the performance value of alternative $A_j$ (1 ≤ j ≤ n) assigned by decision maker p (1 ≤ p ≤ k) under criterion $K_j$ (1 ≤ j ≤ m).

**Step 2.** Creation of a combined criterion weights matrix

The combined criteria weights matrix is constructed containing the priority values assigned to the criteria by decision makers in Equation (12).

W = $[\widetilde{w}_i]_{mx1}$ (12)

$\widetilde{w}_i = \frac{1}{k} +_{p=1}^{k} \widetilde{w}_i^{p}$ (13)

Here $\widetilde{w}_i^{p}$ is the weighted value of the criteria $K_i$ (1 ≤ i ≤ m) assigned by the decision maker p. (1 ≤ p ≤ k).

**Step 3.** Creating the average solution matrix

The average solution matrix (AV) given in Equation (14) is created.

AV = $[\widetilde{av}_i]_{mx1}$ (14)

$\widetilde{av}_i = \frac{1}{n} +_{j=1}^{n} \tilde{x}_{ij}$ (15)

Here $\widetilde{av}_i$ represents the average solution values of the alternatives for each criterion.

**Step 4**. Calculation of positive and negative distance matrices.

Set B shows the benefit criteria and set N shows the cost criteria. In this step, the positive distance matrix (PDA) from the mean and the negative distance matrix (NDA) from the mean are calculated according to the criterion types (benefit or cost).

PDA = $[\widetilde{pda}_{ij}]_{mxn}$ (16)

NDA = $[\widetilde{nda}_{ij}]_{mxn}$ (17)

$$\widetilde{pda}_{ij} = \begin{cases} \frac{\Psi(\tilde{x}_{ij} - \widetilde{av}_i)}{k(\widetilde{av}_i)}, i \in B \\ \frac{\Psi(\widetilde{av}_i - \tilde{x}_{ij})}{k(\widetilde{av}_i)}, i \in N \end{cases} \quad (18)$$

$$\widetilde{nda}_{ij} = \begin{cases} \frac{\Psi(\widetilde{av}_i - \tilde{x}_{ij})}{k(\widetilde{av}_i)}, i \in B \\ \frac{\Psi(\tilde{x}_{ij} - \widetilde{av}_i)}{k(\widetilde{av}_i)}, i \in N \end{cases} \tag{19}$$

Here $\widetilde{pda}_{ij}$ ve $\widetilde{nda}_{ij}$, represent the positive and negative distance performance values from the average solution values for alternative j on criterion i

**Step 5**. Calculation of weighted positive and weighted negative distances.

By multiplying and summing the obtained criterion weights with the positive and negative distance values, the weighted positive and negative distances for each alternative are calculated using Equation (20) and Equation (21), respectively.

$$\widetilde{sp}_j = +_{i=1}^{m}(\widetilde{w}_i \; x \; \widetilde{pda}_{ij}) \tag{20}$$

$$\widetilde{sn}_j = +_{i=1}^{m}(\widetilde{w}_i \; x \; \widetilde{nda}_{ij}) \tag{21}$$

**Step 6.** Normalising values $\widetilde{sp}_j$ ve $\widetilde{sn}_j$ for all alternatives

The values $\widetilde{sp}_j$ ve $\widetilde{sn}_j$ are normalized for all alternatives using equitions (22) and (23) respectively.

$$\widetilde{nsp}_j = \frac{\widetilde{sp}_j}{max_j(k(\widetilde{sp}_j))} \tag{22}$$

$$\widetilde{nsn}_j = 1 - \frac{\widetilde{sn}_j}{max_j(k(\widetilde{sn}_j))} \tag{23}$$

**Step 7**. Calculation of trapezoidal fuzzy number (MIS) evaluation scores for all alternatives.

The evaluation score value ($\widetilde{as}_j$) for all alternatives is calculated using equation (24).

$$\widetilde{as}_j = \frac{1}{2}(\widetilde{nsp}_j + \widetilde{nsn}_j) \tag{24}$$

**Step 8**. Defuzzification of trapezoidal fuzzy number evaluation scores.

Evaluation scores consisting of trapezoidal fuzzy numbers are clarified using Equation (25). [12].

$$K(\widetilde{as}_j) = \frac{1}{3}\left(a_1 + a_2 + a_3 + a_4 - \frac{a_3a_4 - a_1a_2}{(a_3 + a_4) - (a_1 + a_2)}\right) \tag{25}$$

**Step 9.** Ranking of alternatives.

Alternatives are ranked from largest to smallest, with the one with the highest evaluation score being the best alternative.

## 5. Application and Results

In this part of the study, the steps of the fuzzy EDAS method for the evaluation of 5 armored vehicles are explained. The criteria and references used for the selection of armored vehicle systems are shared in Table 2.

**Table 2.** Literature on Fuzzy EDAS Method

| References | Criteria |
|---|---|
| [41,42] | Engine Power |
| | Dimensions |
| | Fire Power |
| | Range |
| | Gradeability (%) |
| | Armor Thickness |

**Step 1**. Creation of a combined decision matrix for alternatives.
Decision makers evaluate armored vehicles for each criterion using the linguistic terms in Table 3.

**Table 3**. Intuitionistic Fuzzy Linguistic Variables

| **Linguistic Variables** | **Criteria** | **Alternative** |
|---|---|---|
| Very Low Important (VLI) | (0,0,0.1,0.2) | (0,0,1,2) |
| Low Important (LI) | (0.1,0.2,0.2,0.3) | (1,2,2,3) |
| Medium Low (ML) | (0.2,0.3,0.4,0.5) | (2,3,4,5) |
| Medium (M) | (0.4,0.5,0.5,0.6) | (4,5,5,6) |
| Medium Important (MI) | (0.5,0.6,0.7,0.8) | (5,6,7,8) |
| Important (I) | (0.7,0.8,0.8,0.9) | (7,8,8,9) |
| Very Important (VI) | (0.8,0.9,1,1) | (8,9,10,10) |

After evaluating the armored vehicles using linguistic terms, the linguistic terms are converted into the corresponding trapezoidal fuzzy numbers in Table 3. The evaluations of one of the experts are shared in Table 4 as an example.

**Table 4.** Trapezoidal Fuzzy Number Correspondence of Expert Evaluation of Alternatives

| | **K1** | | | | **K2** | | | | **K3** | | | | **K4** | | | | **K5** | | | | **K6** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A1** | 4 | 5 | 5 | 6 | 8 | 9 | 10 | 10 | 2 | 3 | 4 | 5 | 2 | 3 | 4 | 5 | 7 | 8 | 8 | 9 | 7 | 8 | 8 | 9 |
| **A2** | 2 | 3 | 4 | 5 | 7 | 8 | 8 | 9 | 2 | 3 | 4 | 5 | 4 | 5 | 5 | 6 | 5 | 6 | 7 | 8 | 8 | 9 | 10 | 10 |
| **A3** | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 | 4 | 5 | 5 | 6 | 5 | 6 | 7 | 8 | 8 | 9 | 10 | 10 | 7 | 8 | 8 | 9 |
| **A4** | 2 | 3 | 4 | 5 | 7 | 8 | 8 | 9 | 1 | 2 | 2 | 3 | 0 | 0 | 1 | 2 | 5 | 6 | 7 | 8 | 2 | 3 | 4 | 5 |
| **A5** | 4 | 5 | 5 | 6 | 8 | 9 | 10 | 10 | 1 | 2 | 2 | 3 | 2 | 3 | 4 | 5 | 7 | 8 | 8 | 9 | 4 | 5 | 5 | 6 |

The combined decision matrix in Table 5 is created using the evaluations made by the decision makers separately and Equation (10).

**Table 5.** Combined Decision Matrix

| **K1** | **K2** | **K3** |
|---|---|---|

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A1** | 4,0 | 5,0 | 5,0 | 6,0 | 7,7 | 8,7 | 9,3 | 9,7 | 4,0 | 5,0 | 6,0 | 7,0 |
| **A2** | 3,0 | 4,0 | 5,0 | 6,0 | 5,7 | 6,7 | 7,3 | 8,3 | 2,3 | 3,3 | 3,7 | 4,7 |
| **A3** | 2,0 | 2,7 | 3,3 | 4,3 | 4,3 | 5,0 | 6,0 | 6,7 | 4,0 | 5,0 | 5,0 | 6,0 |
| **A4** | 3,7 | 4,7 | 5,3 | 6,3 | 6,3 | 7,3 | 7,7 | 8,7 | 1,7 | 2,3 | 2,7 | 3,7 |
| **A5** | 3,7 | 4,7 | 5,3 | 6,3 | 6,0 | 7,0 | 8,0 | 8,7 | 4,3 | 5,3 | 5,7 | 6,7 |
| | **K4** | | | | **K5** | | | | **K6** | | | |
| **A1** | 2,7 | 3,7 | 4,3 | 5,3 | 5,7 | 6,7 | 7,3 | 8,3 | 7,3 | 8,3 | 8,7 | 9,3 |
| **A2** | 4,0 | 5,0 | 5,0 | 6,0 | 4,0 | 5,0 | 6,0 | 7,0 | 6,0 | 7,0 | 8,0 | 8,7 |
| **A3** | 3,3 | 4,3 | 4,7 | 5,7 | 7,0 | 8,0 | 9,0 | 9,3 | 5,0 | 6,0 | 6,0 | 7,0 |
| **A4** | 2,3 | 3,0 | 4,0 | 5,0 | 5,3 | 6,3 | 6,7 | 7,7 | 5,0 | 6,0 | 7,0 | 7,7 |
| **A5** | 2,3 | 3,3 | 3,7 | 4,7 | 4,7 | 5,7 | 6,3 | 7,3 | 6,0 | 7,0 | 7,0 | 8,0 |

In this step, decision-makers evaluate the criteria using the linguistic terms in Table 3 and then convert them into fuzzy numbers corresponding to the linguistic terms again using Table 3. Finally, using Equation (13), the matrix of combined criterion weights given in Table 6 is obtained. The resulting order of importance of criteria can be seen in Figure 1 after the criterion weights.

**Table 6**. Combined Decision Weights

| **K1** | | | | **K2** | | | | **K3** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,4 | 0,5 | 0,6 | 0,7 | 0,7 | 0,8 | 0,9 | 0,9 | 0,4 | 0,5 | 0,5 | 0,6 |
| **K4** | | | | **K5** | | | | **K6** | | | |
| 0,3 | 0,4 | 0,4 | 0,5 | 0,7 | 0,8 | 0,8 | 0,9 | 0,7 | 0,8 | 0,9 | 0,9 |

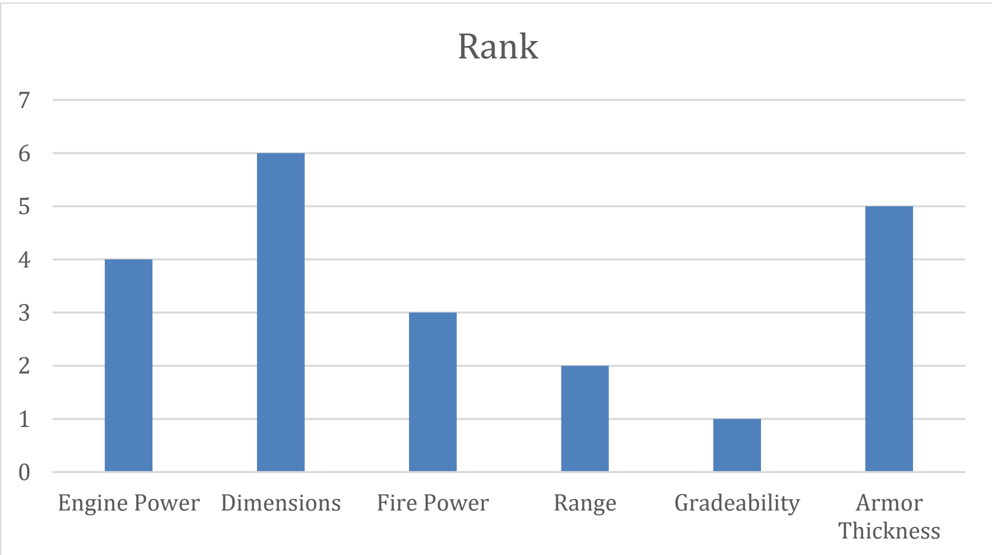


**Figure 1**. Importance Ranking of Criteria

When Figure 1 is examined, considering that the nature of war has evolved from field to city wars, the prominence of dimensions and armor thickness values highlights the consistency of expert opinions. Similarly, due to city wars, the value of the gradeability criterion was at the bottom.

**Step 3.** Creating the average solution matrix.

Using Equation (15), the average solution matrix in Table 7 is obtained by averaging the performance values of all alternatives for each criterion.

**Table 7.** Combined Decision Weights

| K1 | | | | K2 | | | | K3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,9 | 3,9 | 4,3 | 5,3 | 6,0 | 6,9 | 7,7 | 8,4 | 5,3 | 6,3 | 7,1 | 7,9 |
| **K4** | | | | **K5** | | | | **K6** | | | |
| 3,3 | 4,2 | 4,8 | 5,8 | 3,3 | 4,2 | 4,6 | 5,6 | 5,9 | 6,9 | 7,3 | 8,1 |

**Step 4**. Calculation of positive and negative distance matrices.

In this step, paying attention to the fact that the criteria are benefit and cost based criteria, the positive distance matrix from the mean is obtained by using Equation (18) and the negative distance matrix from the mean is obtained by using Equation (19). Since all the criteria for armored vehicle selection are benefit-based, parts of the criteria of the relevant equations were used.

**Step 5**. Calculation of weighted positive and weighted negative distances.

For each alternative, weighted positive distances are calculated using Equation (20) and weighted negative distances are calculated using Equation (21). In this step, criterion weights consisting of trapezoidal fuzzy numbers in Table 6 were used.

**Step 6.** Normalising values $\widetilde{sp}_j$ ve $\widetilde{sn}_j$ for all alternatives

Weighted positive distances are normalized using Equation (23), weighted negative distances are normalized using Equation (23). Normalized values are given in Table 8.

**Table 8**. Normalized Weighted Positive and Negative Distances

| | Positive | | | | Negative | | | |
|---|---|---|---|---|---|---|---|---|
| **A1** | -0,5 | 0,2 | 0,7 | 1,8 | -1,6 | -0,3 | 0,5 | 1,5 |
| **A2** | -0,6 | -0,1 | 0,3 | 1,1 | -2,0 | -0,2 | 0,8 | 2,0 |
| **A3** | -0,8 | 0,0 | 0,6 | 1,8 | -0,9 | 0,4 | 1,0 | 1,9 |
| **A4** | -1,0 | 0,4 | 1,3 | 3,2 | 0,4 | 0,9 | 1,1 | 1,3 |
| **A5** | -0,4 | 0,0 | 0,4 | 1,1 | -2,0 | -0,1 | 1,1 | 2,3 |

**Step 7**. Calculation of trapezoidal fuzzy number (MIS) evaluation scores for all alternatives.

Trapezoidal fuzzy number evaluation scores given in Table 15 for all alternatives are calculated using Equation (24).

**Step 8**. Defuzzification of trapezoidal fuzzy number evaluation scores.

The trapezoidal fuzzy number evaluation scores ($\widetilde{as}_j$) in Table 15 are defuzzified using Equation (25), and the defuzzified evaluation scores (k($\widetilde{as}_j$)) are calculated.

**Step 9.** Ranking of alternatives.

The current situation is shared in Figure 2 when the alternatives are ranked from largest to smallest according to their evaluation scores.

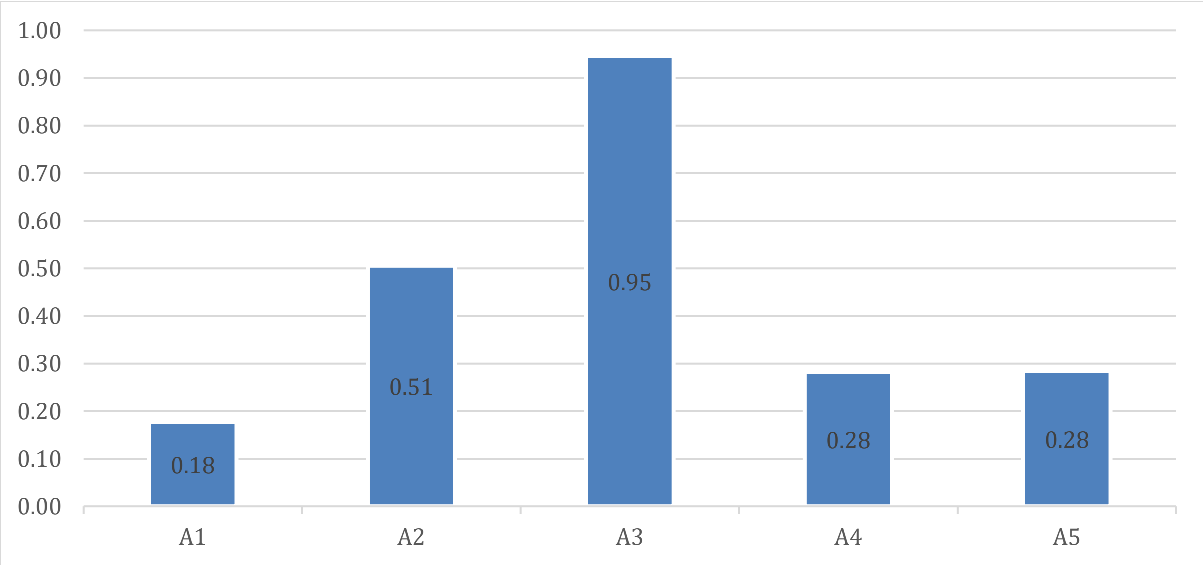


**Figure 2**. Ranking of Alternatives and Final Scores

Figure 2 shows that the order for the best armored vehicle is A3 > A2 > A4 = A5 > A1. When the rankings of the alternatives were examined, the fact that the A3 alternative was the superior tool in terms of dimensions and armor thickness brought the alternative to the first place. Although the A1 alternative is very good in greadability and superior in terrain, it took the last place due to evaluations with high weight criteria.

## 6. Conclusions

In today's asymmetric combat environment, many military experts are working on new doctrines that include wheeled armored vehicles, which are touted as a cheap and effective solution. Countries make many expenditures in line with their defense needs, and military vehicles constitute a significant part of these expenditures. Military vehicles can be imported by countries or produced with their own means. However, when determining the vehicle, many different criteria should be taken into consideration, such as the features of the vehicle needed. These criteria may vary depending on the purpose of the operation, the equipment the enemy has and the region where it is carried out. In this study, the problem of selecting tactical wheeled armored vehicles, which has been one of the indispensable vehicles of the battlefield from past to present, is discussed. The geography, purpose and scope of the operations were discussed in detail and the selection of 5 vehicles according to 6 different criteria was made with the Type-1 Fuzzy EDAS method. During the evaluation, 6 main criteria were taken into account. For each case, the weighting of the criteria is different. For example, while speed and firepower are important in open terrain, obstacle clearance ability and armor thickness come to the fore in residential areas. Expert opinions were used to weight the criteria. It was evaluated that the selected vehicles could operate in various areas such as residential areas, mountainous terrain, and open terrain.

Especially since most of the battles experienced today are in the form of residential operations; trenches, obstacles and barricades often pose obstacles in these urban wars. The obstacle crossing abilities of the armored personnel carriers to be used in this environment are of great importance. On the other hand, the obstacle passing criterion is important in battles in mountainous terrain and open areas, as well as in battles in residential areas. Especially in mountainous terrain, the mobility of vehicles must be above a certain level so that the vehicles do not get stuck on the road or get stuck on a height or in a ditch. Most of today's conflicts take place in residential areas, within buildings and pillboxes, for long periods of time, with the support of armored vehicles and under the threat of snipers. Therefore, high firepower emerges as an important factor. The importance of large-scale and various types of powerful ammunition increases in terms of taking enemy elements hiding inside buildings or behind trenches under fire. Ammunition consumption is quite high in today's battles. Therefore, strong firepower is of great importance for armored vehicles. While in the past there were no gun turrets on wheeled personnel carrier vehicles, today it has become an indispensable need.

Military activities or operations carried out in mountainous terrain continue in various parts of the world today, as in the past. The steep and rugged nature of the terrain makes transportation difficult, which shows us the importance of the engine power of the military vehicle. Criteria such as engine power and obstacle overcoming ability are of great importance for the vehicle's mobility in this type of terrain. Similarly, in operations carried out in open fields and plains, the engine power that provides the performance and speed of the vehicle is of great importance in order to reduce the risk of being targeted and to transport soldiers to the conflict environment as soon as possible. The basic principle in a battle is that the operation is carried out according to the vehicle with the lowest speed. Therefore, the performance of the vehicles is of great importance. The recent conflicts between Russia and Ukraine draw attention to operations carried out in open fields. Open land is a zone with many negative factors. When evaluated from a military perspective, the risk of being a target of long-range anti-tank missiles is high because the visibility range is quite high. Therefore, vehicles with high maneuverability and speed should be preferred. It is important for such vehicles to be flexible in flat terrain to achieve the operation. In wars fought in flat and desert areas; The ground structure of the desert terrain makes it difficult for vehicles to move forward. Especially in rainy weather, there is a risk of mud and swamps in soft ground areas. This situation is especially negative for tactical wheeled vehicles compared to tracked vehicles. However, since all vehicles considered within the scope of the study are tactical wheeled armored personnel carriers, this situation was not taken into account.

The greatest danger and risk in today's wars carried out in mountainous terrain, open areas or residential areas are IEDs and anti-tank weapons. In addition, snipers' armor-piercing ammunition is an important threat. For these reasons, another important criterion for armored vehicles is armor thickness. It is an inevitable fact that, thanks to the developing armor technology today, armored vehicles targeted by IEDs or anti-tank weapons do not cause loss of life or cause less casualties. On the other hand, it is an expected fact that, thanks to its design and armor, a vehicle that has been hit can continue the battle and safely remove its personnel from the battle zone. For this reason, one of the important criteria that should be considered when choosing a vehicle is armor thickness.

The range of wheeled medium-class armored vehicles carrying personnel is a desired feature in terms of traveling for long periods of time without refueling or being left without fuel in a battle environment. Vehicles with as long a range as possible are preferred to safely transport a large number of personnel over long distances. The large number of personnel to be moved brings with it the need for large sizes. The larger the size of the vehicle, the more personnel it can carry. However, increasing the size has both advantages and disadvantages. Especially in residential battles, the turning circle and mobility of vehicles decrease. In environments where there are streets, vehicles cannot turn and in some narrow streets they cannot move and get stuck on the roads. Another disadvantage is that the large size increases the possibility of the vehicle being a target, or rather being shot. As their size increases, the probability of being hit by rockets and missiles increases when carrying more soldiers. For this reason, the criterion regarding the size of the vehicle is also important.

Considering the situations of all these military elements, 6 critical level important criteria that can change the course of the war were evaluated as a result of the analysis and their importance weights were calculated for the selection of military armored vehicles. In the selection of tactical wheeled armored vehicles to be preferred for operations; high maneuverability, obstacle clearance capacity, armor, firepower, vehicle performance (mobility), high personnel carrying capacity, range and small size stand out compared to other features. When we analyze the 5 vehicles, the preferred vehicles for various types of operations are Tulpar ACV produced by OTOKAR in the 1st place, Altuğ ACV 8x8 produced by BMC in the 2nd place, and Kaplan YN-ACV produced by FNSS in the 3rd place. Akrep 4x4 produced by OTOKAR is in the 26th place, Kaya II 4x4 is in the 27th place, while the Ilgaz II vehicle produced by NUROL is in the 28th place.

Armored vehicles have gone through many evolutions in their journey from the early ages when chariots were used to the present day. The need for armored vehicles, whose effectiveness increases with network-centric warfare capability and becomes a force multiplier in area control, will become even more important in the future. As a result of the study, a methodology was presented to decision makers for selecting the most suitable tactical wheeled armored personnel carrier vehicle, depending on the purpose of the operation, its type and the structure of the terrain. Choosing the right vehicle; It is of great importance in terms of the safety of soldiers, the success of the operation and the financial burden. Changes in today's operational and war situations, developments in new armored vehicles and technologies, and diversification of needs necessitate vehicle selection according to analytical analysis. A methodology is presented with this study. In the EDAS method, which is blurred with a Type-1 fuzzy set, trapezoidal fuzzy numbers are preferred and the selection of the armored vehicle according to various criteria is made according to a scientific methodology. Especially in this sector where there are many manufacturers, it has been scientifically proven which vehicle selection will be most effective in terms of conflict environment. The methodology presented in this study can be handled differently according to a greater number of alternatives and criteria, and can also be used in the selection of other weapon systems. Considering more or different criteria and making comparative analyzes using different MCDM methods are among the studies planned to be carried out in the future.

**Conflicts of Interest**

The author declare no conflicts of interest.

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