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Fuzzy LBWA Framework for Evaluate the Criteria Affecting Ammunition Consumption

Kemal Gürol Kurtay[1,*], Hakan Ayhan Dağıstanlı[2,]

1 Department of Industrial Engineering, Turkish Military Academy, National Defence University, Ankara, Turkiye
2 Department of Industrial Engineering, Turkish Military Academy, National Defence University, Ankara, Turkiye

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ABSTRACT

One of the most important aspects of military logistics is ammunition. Ammunition is one of the most crucial materials to consider in order to win a war. Therefore, this study examines the criteria affecting ammunition consumption. The aim is to provide war planners with an analytical perspective. Military expert opinions were consulted for the evaluation of the criteria, and fuzzy multi-criteria decision-making (FMCDM) was chosen as the solution methodology. The Level Based Weight Assessment (LBWA), commonly used in military problems in the literature, was employed as the method. The most important criterion is the number of enemy targets. This is followed by interceptions and aerial photographs containing potential targets obtained through intelligence activities. Finally, the changes in criterion weights were examined using different scenarios for the coefficient of elasticity value, and the results were validated.

1. Introduction

Historically, the development of armies and logistics activities has progressed in parallel [1]. As the size of armies and wars increased, so did the scale of logistics activities. Logistical activities for armies must be planned with great detail. Disruptions in logistics negatively impact military operations after a certain period. Furthermore, in the crisis environment that begins with the start of an operation, factors such as embargoes between countries and material shortages make meeting logistical needs difficult or very costly. One of the most important of these materials is ammunition. It is an indispensable resource for firepower and sustainment, elements of combat power shown in Figure 1 [2].

Today, ammunition is a critical material used to provide firepower, a function of combat power, for armies, and its logistics is an extremely important activity requiring many areas of expertise. Accurately estimating the amount of ammunition to be used by armies is crucial. Because the capabilities of logistical elements used by armies are limited, the activities carried out using these elements are extremely vital for the success of armies. These activities include the supply of water and food for army personnel, and the supply of equipment. Accurate ammunition estimation

* kemalgurol.kurtay@msu.edu.tr

provides flexibility in ensuring the logistics of other logistical elements that are as vital as ammunition [3].

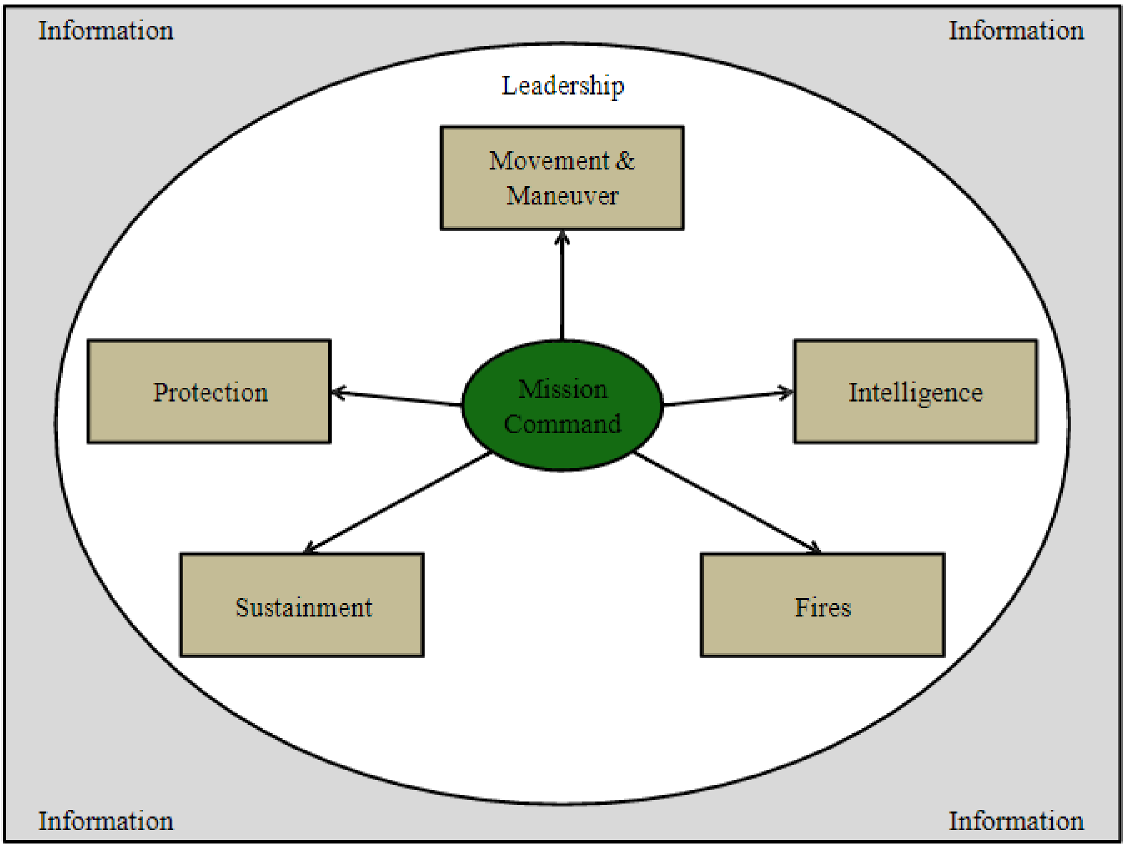

Figure 1. The elements of combat power [2,4].

At this stage, examining ammunition consumption from a close perspective is extremely important and offers several advantages [5]. Firepower, the dominant factor influencing the outcome of war on the battlefield, is provided by ammunition [6]. Ammunition is the tool used to defeat and neutralize the enemy, and military units use it to obstruct, conceal, channel enemy elements to a specific point, clear passages through minefields when necessary, and protect themselves. Because of its vital importance, it is the most needed and consumed supply item on the battlefield. Ammunition encompasses many issues requiring expertise on the battlefield. The special storage requirements, inspection, maintenance, and final processing of ammunition are all matters requiring specialized knowledge [7,8]. This increases the importance of ammunition. Ammunition procurement is one of the most difficult supplies to obtain [9]. The insufficient production capacities of countries, the difficulties in importing ammunition due to diplomatic relations and embargoes between states, all increase its value.

The estimated amount of ammunition used by armies varies periodically. The main reason for this is that with the parabolic pace of technological development, the accuracy of weapons has improved, resulting in a decrease in the amount of ammunition used. The amount of ammunition consumed by the American Army in World War II and the Gulf War are important examples of this [3]. In the post-Cold War era, conventional warfare has lost its importance, and the concepts of low- and medium-intensity conflict and hybrid warfare have come to the forefront in the context of combating terrorist organizations. As a result, European countries, in particular, reduced their defense budgets and did not make large investments in defense because they thought that conventional wars would not occur in Europe after the Cold War. However, the recent Russia-Ukraine war has shown that conventional warfare has not lost its importance and that the European continent could face a conventional war situation at any moment. Furthermore, the Russia-Ukraine war, which proved insufficient in providing ammunition to Ukraine, taught European countries that they would be inadequate in defending themselves in a conventional war situation [10, 11].

Examples from military history and current warfare demonstrate that having sufficient ammunition and uninterrupted supplies on the battlefield significantly impacts the outcome of battles. To predict the amount of ammunition needed on the battlefield, it's necessary to examine the factors influencing consumption. This study employs fuzzy multi-criteria decision-making (FMCDM) methodology to investigate the criteria affecting ammunition consumption.

Military decision problems are critical problem areas requiring expert opinions [12, 13]. Providing a decision support model for the increasingly complex warfare environment is quite challenging due to modern technologies. Therefore, FMCDM methods are preferred as a fundamental analytical framework for problems where expert judgment, qualitative evaluation, and partial information play a central role [14,15]. Unlike classical decision models based on precisely calculated or identified numerical inputs, FMCDM methods allow military experts to analytically reflect their past experiences and forecast/foresight approach to events in the solution. In this study, a generic scenario has been created to evaluate the criteria affecting ammunition consumption. Within the generic scenario, the number of attacks by the enemy, the number of enemy radio interceptions/interceptions, the number of aerial photographs of enemy units, the number of positions destroyed/planned to be destroyed daily, and the number of operation days are considered. The aim is to evaluate the SCOR performance attributes using the Level Based Weight Assessment (LBWA) method from the MCDM methods. In this context, the criterion weights for the SCOR performance attributes are determined using the LBWA method in line with expert opinions.

Section 2 presents a literature review of the method. Section 3 outlines the methodology, Section 4 describes the application for generic scenario, and Section 5 presents the results.

2. Literature Review

Since its proposal by Žižović and Pamučar [16] in 2019, the LBWA method has contributed to the solution of various real-life decision problems. Studies carried out with the LBWA method in the literature can be summarized as shown in Table 1.

Table 1. LBWA yöntemi için literatür özeti

Year	Reference	Method	Area
2020	[17]	LBWA, MAIRCA, Interval fuzzy numbers	Military-Weapon
2020	[18]	LBWA, Z-MAIRCA	Military-Camp
2020	[19]	LBWA, PIPRECIA	Education
2020	[20]	LBWA, MACBETH, Fuzzy RAFSI	Healthy -COVID-19

2020	[21]	LBWA, fuzzy LBWA-WASPAS-H decision making model	Airport
2021	[22]	LBWA, CODAS, interval rough number	Renewable Energy
2021	[23]	LBWA, Fuzzy MABAC	Military-
2021	[24]	LBWA, BWM, CoCoSo	Healthy
2021	[25]	LBWA, picture fuzzy environment	Social Enterprise Systems
2022	[26]	Fuzzy LBWA, Fuzzy CoCoSo'B	Container Ports
2022	[27]	LBWA-G, EDAS-G	Smart City
2022	[28]	LBWA, MULTIMOOSRAL, Spherical Fuzzy LBWA	Micro, Small & Medium Enterprises
2023	[29]	LBWA, Z-MABAC	Strategy Selection
2023	[30]	Fuzzy LBWA	Fast-Moving Consumer Goods'
2023	[31]	Picture Fuzzy LBWA–CoCoSo	Strategy Selection
2023	[32]	BWM, LBWA, CoCoSo	Food Sector
2023	[33]	Fuzzy BWM, Fuzzy LBWA, Fuzzy CoCoSo	IoT Gateway Selection
2024	[34]	LBWA, CRITIC, RAFSI, Fermatean cubic fuzzy method	Energy
2024	[35]	LBWA, MARCOS, picture fuzzy environment	Assessment of Ports
2025	[36]	Fuzzy LBWA, Fuzzy LMAW, MARCOS	Banking
2025	[37]	F-LBWA and I-RAWEC Methods	Facility Location Selection
2025	[38]	IVF-LBWA and IVF-MAIRCA	Sustainable Project Selection

3. Methodology

The application stages of the LBWA method are discussed in detail, and each step is explained systematically [16]:

Step 1: Selecting the Most Important Criterion

In the first step, the most critical criterion, $S = \{k_1, k_2, \dots, k_n\}$ is determined from all the criteria according to the decision-makers opinion. This selected criterion will serve as a reference point in subsequent stages. Let's say the most important criterion is k_1.

Step 2: Leveling the Criteria

The decision-maker subdivides the criteria within the set S into subsets according to their importance as follows:

S_1: The most important criterion, k_1, is either equal in importance to the criteria in this group or at most twice as important (except for exactly twice).

S_2: The most important criterion, k_1, has at least twice (including 2) and at most three times the importance of the other criteria in this group (excluding exactly three times).

S_3: The most important criterion, k_1, has at least three times (including 3) and at most four times the importance of the other criteria in this group (excluding exactly four times).

S_t: The most important criterion, k_1, has at least t times (including t) and at most t+1 times greater significance than the criteria in this group. By applying the rules presented above, the decision-maker determines the classification of the observed criteria, that is, they group the criteria according to their significance levels (except for the full t+1 times).

If the importance of the criterion is denoted by $s(k_j)$ then j∈{1,2,…,n} and $S = S_1 \cup S_2 \cup \ldots \cup S_t$ can be written and i∈{1,2,…,t} can be found using the following Equation (1).

$$S_i = \{k_{i_1}, k_{i_2}, \ldots, k_{i_t}\} = \{C_j \in S: i \leq s(k_j) < i + 1\} \quad (1)$$

Step 3: Assigning Integer Values to Criteria.

The criteria at the levels in the previous step are compared according to their importance. Integer assignments $\left(I_{i_p} \in \{0,1,\ldots,\varphi\}\right)$are made to the criteria at each level. The most important criterion at that level is assigned “0”, and the criterion considered to be of secondary importance is assigned “1”, and so on. For the most important criterion C_i, the integer assignment is $I_i = 0$. In this case, if the p-th criterion is more important than the q-th criterion, the integer assignments are $I_p < I_q$, or if these criteria are of equal importance, the integer assignments are $I_p = I_q$. With r being the maximum integer assignment, the following Equation (2) is obtained.

$$r = \text{maks}\{|S_1|, |S_2|, \ldots, |S_k|\} \quad (2)$$

Step 4: Determining the Elasticity Coefficient

The ϕ value obtained in the previous step forms the basis for determining the elasticity coefficient. It is determined as $\varphi_0 > \varphi$, where $\varphi_0(\varphi_0 \in R)$ is the elasticity coefficient.

Step 5: Calculation of Influence Functions

The influence functions of the criteria are calculated with Equation (3), where i: level rank, φ_0: elasticity coefficient, and I_{i_p}: integer assignment.

$$f\left(k_{i_p}\right) = \frac{\varphi_0}{i \cdot \frac{r}{\varphi_0} + I_{i_p}} \quad (3)$$

Step 6: Calculation of Criterion Importance Weights

In this stage, first, the weight of the most important criterion (w_i) is found using Equation (4). After finding the weight of the most important criterion, the importance weights of the other criteria (w_j) are found using Equation (5). Assuming that the most important criterion is C_1;

$$w_1 = \frac{1}{1+f(k_2)+\cdots+f(k_n)} \tag{4}$$

$$w_j = f(k_j).w_1 \tag{5}$$

In 2019, Žižović and Pamucar [16] proposed a new MCDM model that offers some advantages over existing models. However, the model does not adequately address the uncertainty and ambiguity in human judgments. This motivated Pamucar et al. (2020) to introduce a fuzzy extended version of the LBWA from the first article in their study [21]. The procedures of Pamucar et al. (2020) Fuzzy-LBWA adopted in this study were used.

4. Application and Results

In this study, a generic scenario was established. A generic dataset containing 700 days of ammunition use for artillery ammunition was created to examine the criteria affecting ammunition consumption, in accordance with the scenario. For the first four criteria, the combat events considered as variables in Şahin (2025) ammunition estimation study constitute the criteria in this study [39]. Additionally, the number of operation days has been added. This is because the duration of the operation is a crucial criterion to consider in terms of ammunition consumption in combat. Explanations of the criteria are given below.

X_1: Daily Attack Volume

X_2: Interception Volume

X_3: Number of Targets Destroyed

X_4: Number of Aerial Photographs

X_5: Duration of the Operation

As described in Section 3, the first step is to select the most important criterion. The most important criterion has been determined as the number of targets planned to be destroyed. The X_5 criterion is evaluated over 700 days. To enable experts to level the criteria in the second step, data for the generic scenario is given sequentially in Figures 2-6. Figures 2 and 4 model the information obtained after intelligence activities.

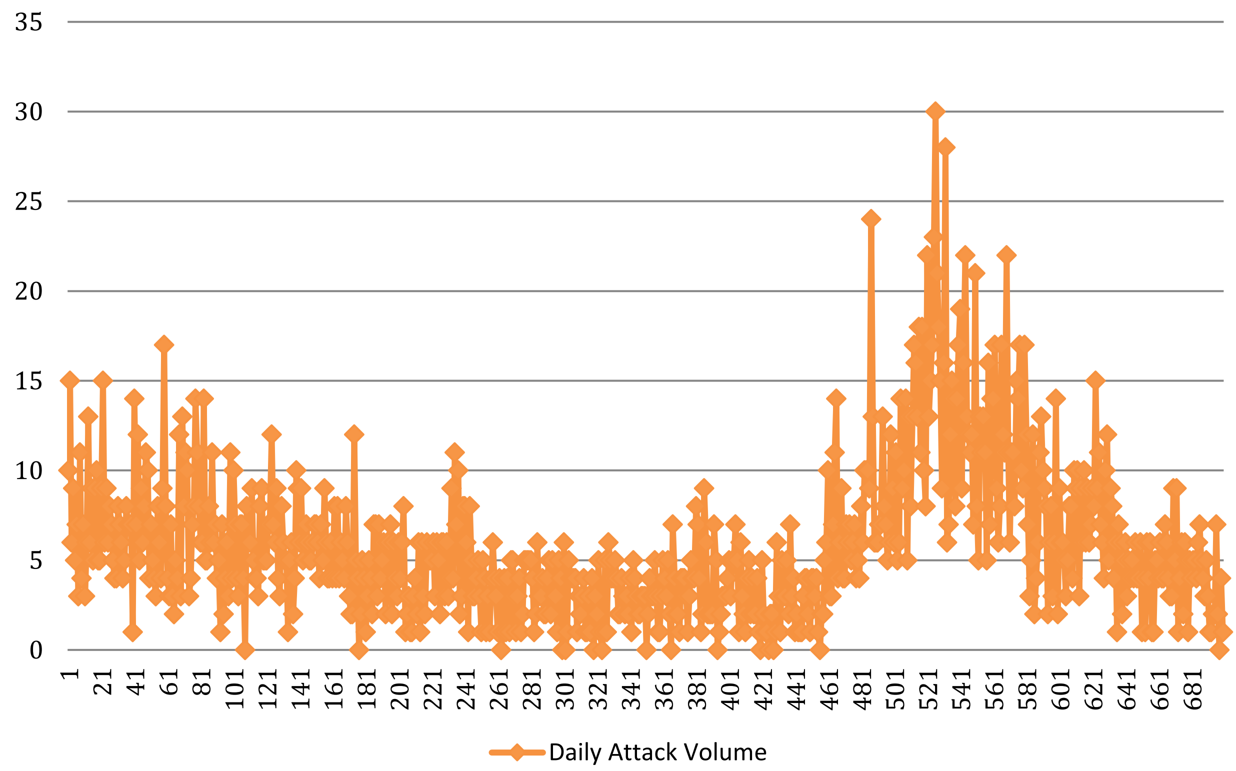

Figure 2. Daily Attack Volume for Generic Scenario

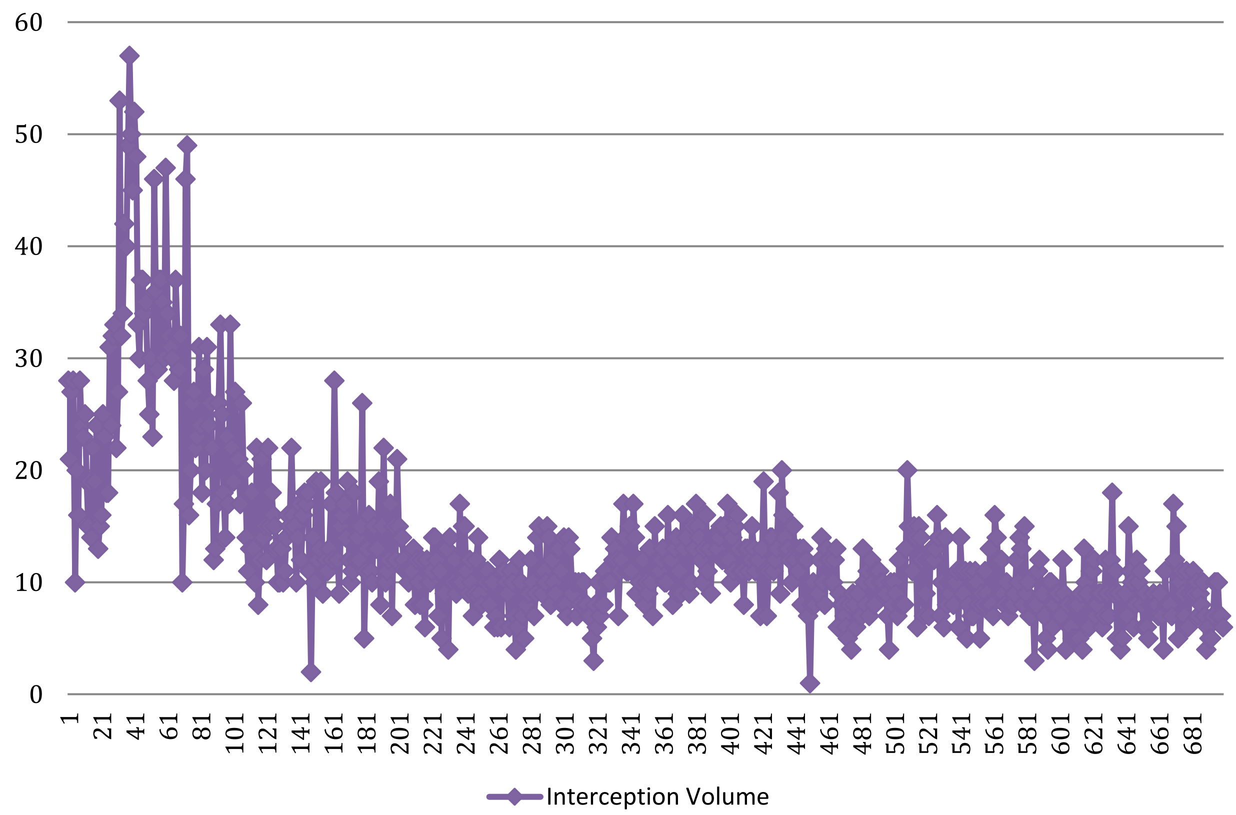

Figure 3. Interception Volume for Generic Scenario

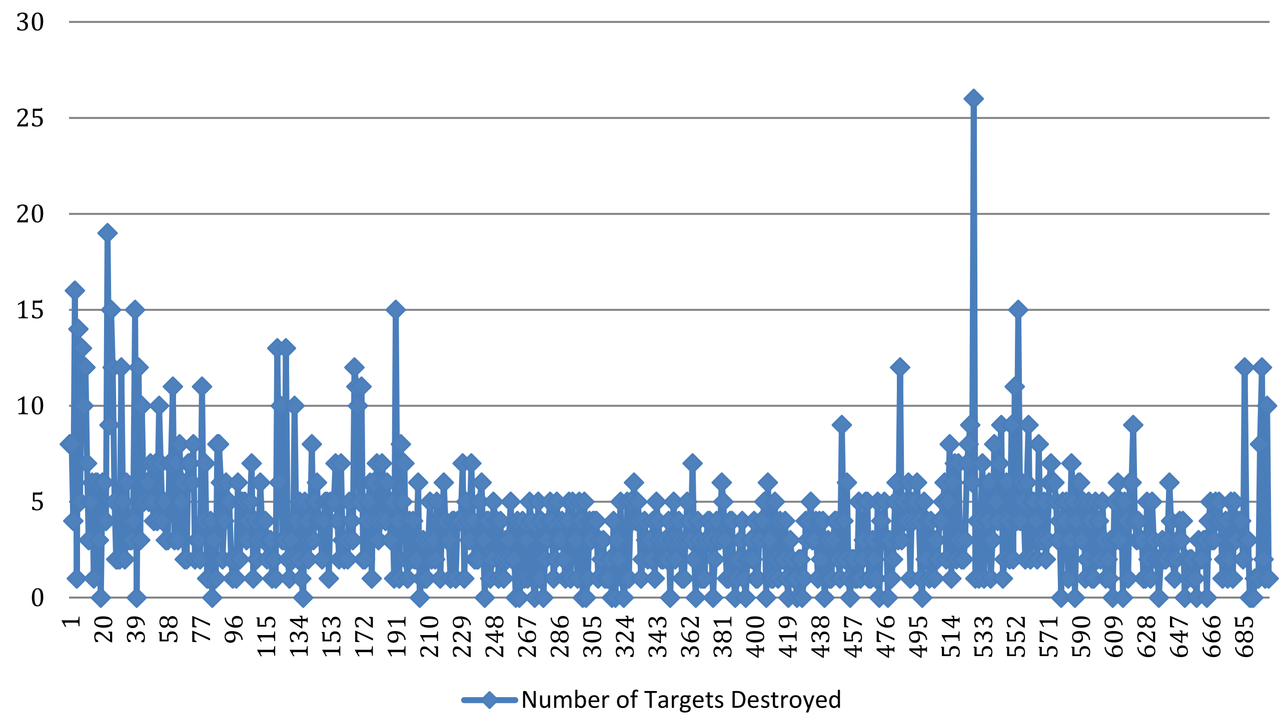

Figure 4. Number of Targets Destroyed for Generic Scenario

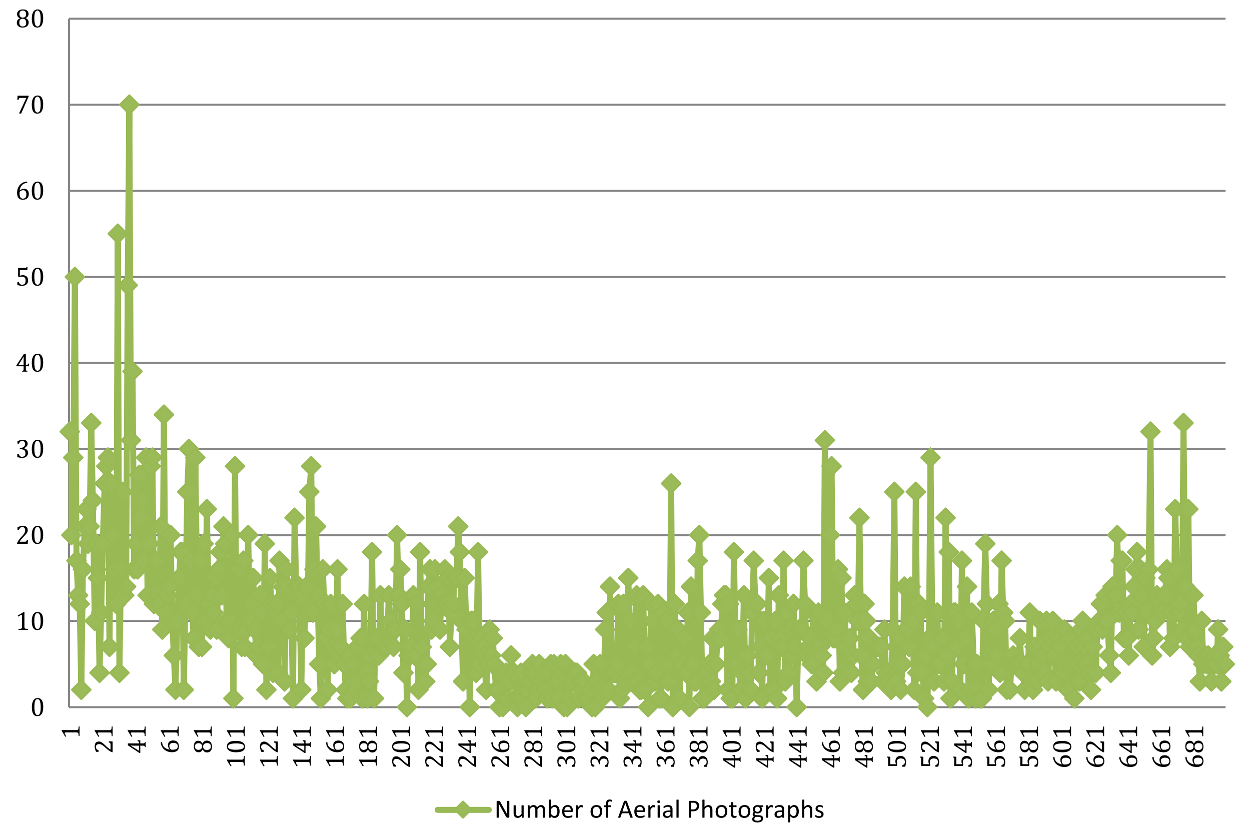

Figure 5. Number of Aerial Photographs for Generic Scenario

Figure 6. Artillery Ammunition Used for Generic Scenario with Decision Criteria

The graphs given in Figures 2 through 6 were evaluated by experts. Thus, the levels given in step 2 were determined as $S_1 = \{k_3, k_4\}$, $S_2 = \{k_2\}$, $S_3 = \{k_1, k_5\}$. The Φ coefficient of elasticity was accepted as 3 for the first scenario. Then, Fuzzy LBWA procedures were applied. The distribution of criterion weights is given in Figure 7.

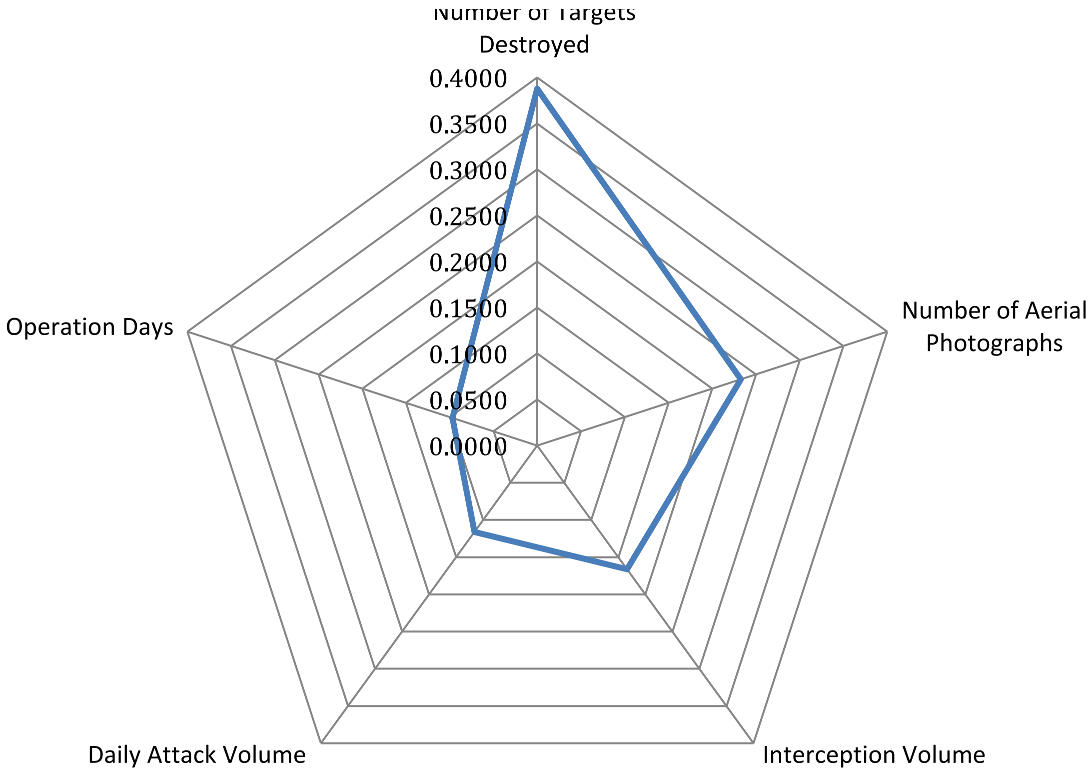

Figure 7. Criteria Weights

Finally, the analysis was updated to see the effects of the change in the elasticity coefficient Φ. Comparative values are given in Figure 8.

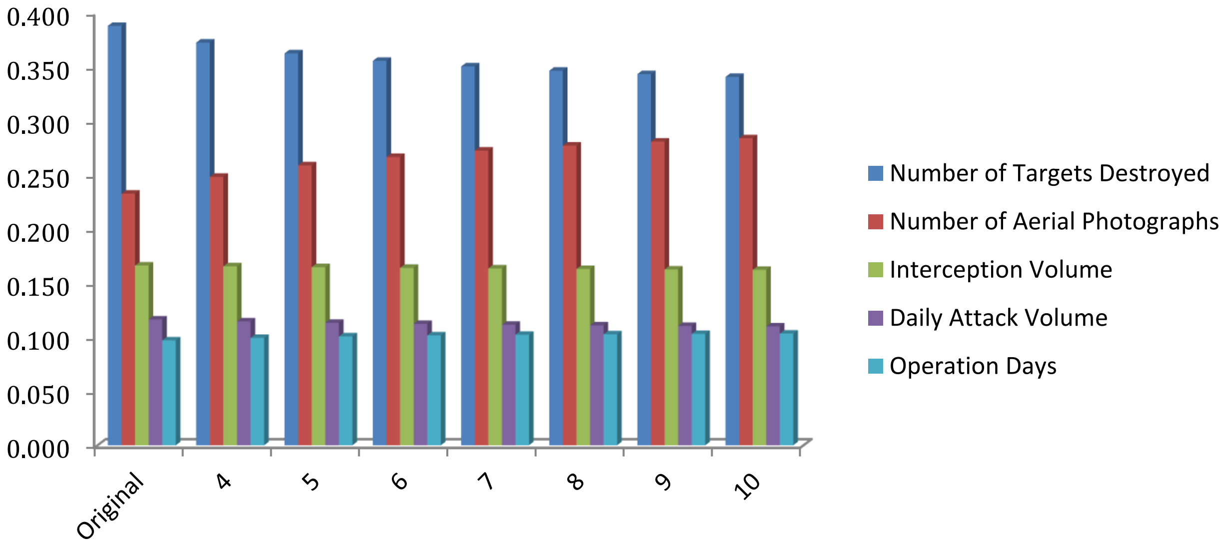

Figure 8. Comparative values for coefficient of elasticity

When Figure 8 is examined, it is seen that in all scenarios, the order is $K_3 > K_4 > K_2 > K_1 > K_5$.

5. Conclusions

The conduct of warfare is an extremely complex environment requiring consideration of a wide variety of parameters. However, the battlefield is full of uncertainties. Armies that make the most accurate predictions about these uncertainties gain many advantages even before the war begins. The amount of food supplies for soldiers, the amount of fuel consumed by vehicles, and the amount of ammunition to be used are some of these uncertainties. Limited or no access to these materials affects the course of the battle. Minimizing this complexity is possible by accurately envisioning the battlefield and preparing it in a way that creates the most favorable conditions for friendly forces. In this study, criteria affecting ammunition consumption were determined using the Fuzzy LBWA method in a generic scenario. The most important criterion is the number of enemy targets. Aerial photographs and interception are the next most important criteria, i.e., intelligence information. Following these are enemy attacks and the number of operation days. This study has several limitations. The scenario was conducted using generic data and a valuable type of ammunition, such as artillery ammunition. The weighting of the criteria may differ for other weapon systems. Results may vary depending on actual data. If military experts' experiences differ for each operation, the criteria may also take on different levels of importance. Future studies could address the problem using different MCDM methods besides LBWA. Comparative analyses could be conducted. The data could be used in mathematical modeling and simulation studies.

Author Contributions

Conceptualization, K.G.K. methodology, H.A.D.; investigation, K.G.K.; resources, K.G.K.; writing—original draft preparation, K.G.K., H.A.D.; writing—review and editing, K.G.K.; visualization, H.A.D.; supervision, K.G.K.; All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

Data will be made available on request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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