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An Interval-Valued Intuitionistic Fuzzy VIKOR Approach for R&D Project Selection in Defense Industry Investment Decisions

Hakan Ayhan Dagistanli[1,*]

[1] Department of Industrial and System Engineering, Turkish Military Academy, National Defense University, Ankara, Turkiye

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ABSTRACT

Defense Industry projects are high-budget projects that take many years, required infrastructure, and go through serious research and development processes. When making investment decisions, solutions obtained with models based on expert opinions and analytical techniques are required. At this point, interval-valued intuitionistic fuzzy (IVIF) methods are a good alternative to eliminate uncertainty, especially in order to evaluate all preference information provided by decision makers. In this study, multi-criteria decision making in the IVIF environment in the defense industry is extended with the VIKOR method. For the application, the literature was examined and 8 different criteria were determined. 4 different alternative projects were evaluated based on these criteria by 3 different decision makers. The results show that the analyzes performed with the VIKOR method in the IVIF environment are similar to the literature. Additionally, there is no study in the literature examining this methodology on the defense industry.

1. Introduction

Projects are sustainable plans with a certain completion time. Investment project is one of the project types and is implemented within a certain period of time and budget limits by using appropriate and correct resources to achieve the previously detailed goal. Defense industry projects cover all activities that affect the future of countries and are defined as important investment projects. These projects directly affect the political, economic and military power of countries in the international arena. At the same time, there is a constant need for innovation and modernization in parallel with the developments in technology, and they appear as complex products that require high technology. For all these reasons, it is of great importance to follow the constantly developing technology [1].

Technological developments in the defense industry and defense expenditures for investment projects carried out in this context are the factors that most affect the development of countries' military power in the field [2]. The budget allocated to defense industry projects has a significant share in the country's economy resources. In this context, it is important to prioritize the selection of

* *Corresponding author.*
E-mail address: rdagistanli@kho.msu.edu.tr

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the most suitable projects during the project selection process in order to use resources effectively. As a result of wrong choices, resources can be wasted and the prestige and effectiveness of countries can decrease.

The defense industry does not seek direct profit, but directly or indirectly affects different sectors of the country's economy with large projects that will ensure the survival of the country. Recently, many countries with modern armies have concentrated on R&D activities in the defense industry and have managed to implement many important projects [3]. Although the percentage share of countries' military expenditures in GDP has decreased over the years, R&D expenditures have increased in the OECD data given in Figures 1 and 2, [4,5].

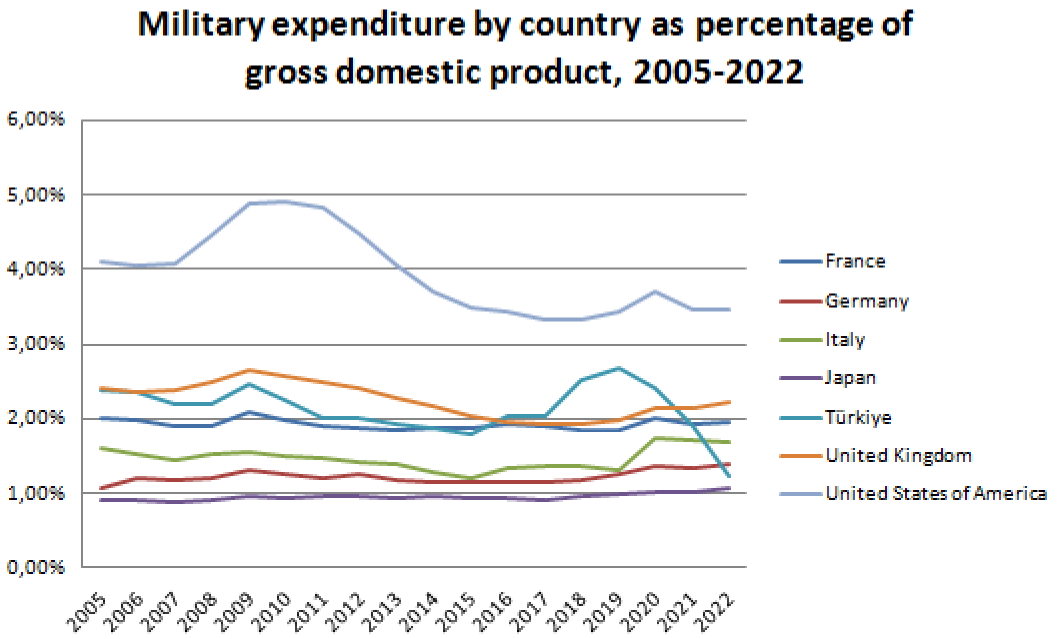

Fig. 1. Military expenditure by country of %GDP

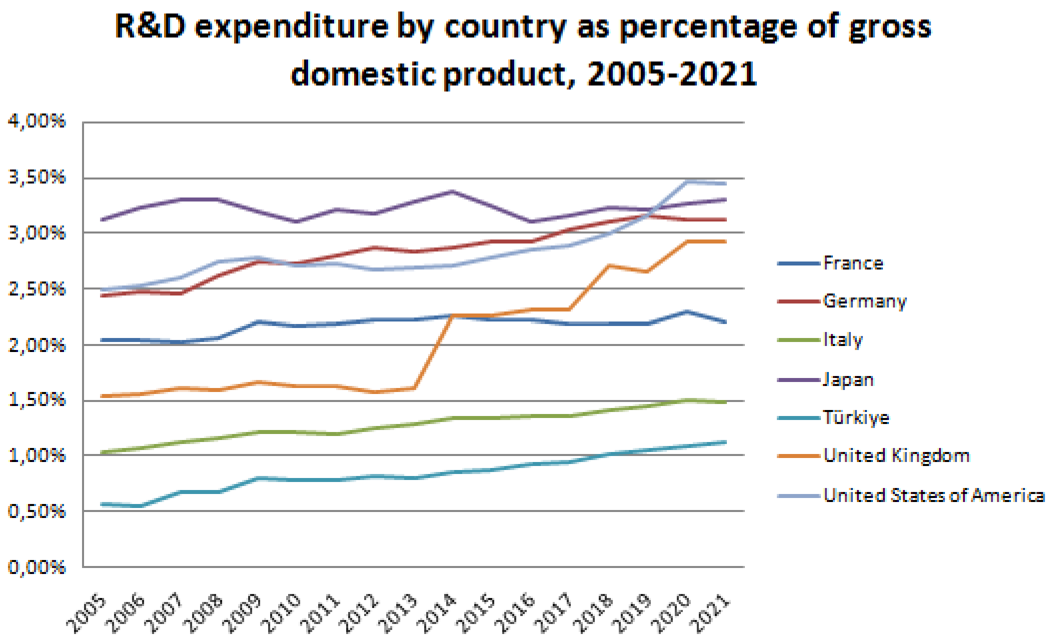

Fig. 2. R&D expenditure by country of %GDP

When Figures 1 and 2 are examined, a decreasing trend in military expenditures has been observed in the period since 2005, while an increasing trend in R&D expenditures is noteworthy. Countries prefer R&D expenditures and projects for domestic production or modernization instead of going directly to the defense acquisition process for military expenditures.

Since the projects carried out in the defense industry are strategic, they must be carried out in a planned manner, effectively and efficiently according to the needs and resources. In order to determine the priorities of the projects carried out correctly and to make effective decision-making, prioritization must be done using analytical methods. For this reason, multi-criteria decision making (MCDM) methods are frequently preferred because they can be successfully applied in the field of defense industry. At the same time, fuzzy MCDM (FMCDM) methods appear to be effective due to the subjectivity of the opinions of military professionals and industry experts.

This study aims to fill the FMCDM gap in the literature regarding defense industry projects and to bring a new perspective to project prioritization, which directly affects project selection. 4 different projects for land, air, ground defense and air defense planned to be carried out in Turkey were discussed. For national and international security reasons these projects are created generically and are not named. They're also just coded. The 8 criteria used to prioritize projects were determined by military professionals using the literature. It has been integrated with the Interval-Valued Intuitionistic Fuzzy Sets (IVIF) VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) Method, which has been proven to be accurate in many different sectors to solve the problem. The number of studies using this method in the literature is quite low, and no study using this method in solving military problems has been found. Expert opinions and project data were modeled in Microsoft (MS) Excel computer program and calculations were made.

The aim of this study is to propose a methodology for project prioritization in the defense industry. Although there are many different studies in the literature, major contributions of this study can be highlighted theoretically as follows: (1) The IVIF VIKOR Method was applied to the military decision-making problem for the first time. (2) The proposed FMCDM methodology allows for a more flexible decision-making process despite the uncertainties in the decision-making process. It also plays a strong role for any military project selection other than land, air, surface-to-air missile (SAM) and air-to-surface missile (ASM). (3) With the proposed methodology, it is possible to establish a balance between precision and confidence through sensitivity analysis by varying the opinions of military professionals on a project-based basis.

There are 5 headings in the study. In the first heading, information about the general purpose of the study was given and the project selection was introduced. In the second heading, a literature summary of studies using MCDM methods in military project selection and studies using the IVIF VIKOR method is given. In the third heading, the method used in the study is explained and its steps are presented. In the fourth title, implementation is included and 4 defense industry projects are examined under 8 criteria. The last title of the study includes the results and comments.

2. Related Literature

When the resource areas allocated by states for the development of science and technology today are examined, it is observed that a significant share is allocated to military projects. At this point, a decision problem arises regarding the selection of military projects. A mistake made in this problem may cause states to face much bigger problems of critical importance in terms of security and economy. Military decision problems are among the relatively few studies studied in the literature and are generally evaluated with MCDM [6-8]. Military projects, on the other hand, are frequently solved with FMCDM in order to include the expressions in the analysis because they require subjective interpretations of professionals [9-12]. There are studies analyzing research conducted with MCDM [13] and FMCDM [14] by considering military problems from a broad perspective. The VIKOR method and its fuzzy variations are frequently used in these studies [15-18].

Many extensions of fuzzy sets have emerged over time as fuzzy set theory develops. It has also begun to be used in traditional Fuzzy decision-making models [19,20]. One of these extensions of fuzzy sets is Intuitionistic Fuzzy Sets (IFS) [21], which have an important place in decision-making and have gained popularity in recent years. IFS theory, the sum of membership degree and non-membership degree is not treated as binary as in traditional fuzzy set approaches. The extended definition presented also helps to represent situations where the decision maker refrains from expressing his or her evaluations. In this proposed extended approach, the degree of abstention of the decision maker is called the Intuitionistic Fuzzy Index (or degree of hesitation). In this way, IFSs provide a richer tool for representing uncertainty than traditional fuzzy sets. This feature of IFSs enables the VIKOR method to be used as a more effective decision method.

In addition to IFSs, early studies proposed IVIF sets (IVIFS) by extending membership and non-membership functions with interval values and improved the working methods and comparison methods of IVIFS [22,23]. IVIFS offers a broader scope for describing fuzzy information than FS and IFS [21], and has received increasing attention in the literature. In the literature, there are two important studies on fuzzy extensions of the VIKOR method [24] and studies using IVIF methodology [25]. The literature summary of the IVIF VIKOR method used in this problem is presented in Table 1.

Table 1
Literature Summary for IVIF-VIKOR Method

Year	References	Area	Year	References	Sector
2011	[26]	Supplier Selection	2019	[35]	Tourism Projects
2011	[27]	Strategic	2020	[36]	Investment Projects
2013	[28]	Investment	2020	[37]	Energy Industry
2013	[29]	Partner Selection	2021	[38]	Traffic
2014	[30]	Teorical	2021	[39]	Vaccine Selection
2017	[31]	Teorical	2022	[40]	Logistics Location Selection
2018	[32]	Technology Selection	2022	[41]	Supplier Selection
2019	[33]	Medical Device Selection	2023	[42]	Technology Strategies
2019	[34]	Robot Selection	2023	[43]	Energy Industry

3. Methodology

3.1 Interval-Valued Intuitionistic Fuzzy Sets

Multi-criteria decision making (MCDM) methods are an effective field of operations research that offers decision makers many tools for complex decision-making problems. There is an extensive MCDM literature research study regarding MCDM methods [32]. This study comprehensively analyzes MCDM tools with their application areas. The VIKOR method, one of these decision-making tools, was used in the study. Additionally, all information provided by decision makers is expressed as IVIF decision matrices. The extended VIKOR method, in which each matrix element is characterized by an interval-valued IFS, is discussed.

$A = \{a_1, a_2, \dots, a_n\}$ represents a set with n alternatives and $D = \{d_1, d_2, \dots, d_l\}$ represents a set with l decision makers for the MCDM problem. The weights of the decision makers in this cluster are shown as a vector $\Theta = (\Theta_1, \Theta_2, \dots, \Theta_l)^T$ and the condition $\Theta_k \geq 0$ $k = 1,2,3, \dots, l$ is met. In addition, the sum of the weights of the decision makers can be represented by the equation $\sum_k^l \Theta_k = 1$. $C = \{c_1, c_2, \dots, c_n\}$ refers to the criterion set with m elements.

The weights given by decision makers for the criteria are represented in the interval-valued heuristic Fuzzy decision matrix and expressed as $R^{(k)} = (\check{r}_{ij}^{(k)})$. The decision matrix is shown in the Table 2, in line with the opinions of the decision maker d_k $(k = 1,2, \dots, l)$:

Table 2
Decision Matrix

	a_1	a_2	.	.	.	a_n
c_1	$\check{r}_{11}^{(k)}$	$\check{r}_{12}^{(k)}$	.	.	.	$\check{r}_{1n}^{(k)}$
c_2	$\check{r}_{21}^{(k)}$	$\check{r}_{22}^{(k)}$	.	.	.	$\check{r}_{2n}^{(k)}$
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
c_m	$\check{r}_{m1}^{(k)}$	$\check{r}_{m2}^{(k)}$	$\check{r}_{m3}^{(k)}$	.	.	$\check{r}_{mn}^{(k)}$

In the decision matrix, it is shown as $\check{r}_{ij}^{(k)} = \langle [a_{ij}^{(k)}, b_{ij}^{(k)}], [c_{ij}^{(k)}, d_{ij}^{(k)}] \rangle$ Interval value heuristic Fuzzy value presents the performance degree of alternative $a_j \in A$ based on criterion $c_i \in C$ through the decision maker opinion $d_k \in D$. In this notation, the first part of the mathematical representation of the opinion expressed by the decision maker $d_k \in D$, $[a_{ij}^{(k)}, b_{ij}^{(k)}]$ expresses the degree to which the alternative $a_j \in A$ satisfies the criterion $c_i \in C$. The secondary part $[c_{ij}^{(k)}, d_{ij}^{(k)}]$ shows the degree of dissatisfaction of alternative $a_j \in A$ based on criterion $c_i \in C$. In addition, the following situation exists:

$$[a_{ij}^{(k)}, b_{ij}^{(k)}] \subset [0,1], [c_{ij}^{(k)}, d_{ij}^{(k)}] \subset [0,1], b_{ij}^{(k)} + d_{ij}^{(k)} \leq 1, i = 1,2, \dots, m; j = 1,2, \dots, m \quad (1)$$

In order to apply the VIKOR method in the group decision-making process, it is first necessary to transform all individual decisions into group opinion. Some methods of combining decision-maker opinions have been proposed in the literature for this purpose [44,45]. At this stage, all decision matrix values are collected and the collective range values are transformed into an intuitive Fuzzy decision matrix. In this study, the following transformation process is considered on the basis of decision makers:

$$\check{r}_{ij} = IVIF_{a,Y}\left(\check{r}_{ij}^{(1)}, \check{r}_{ij}^{(2)}, \dots, \check{r}_{ij}^{y(l)}\right) = \left(\check{r}_{ij}^{(y(1))}\right)^{a1} \otimes \left(\check{r}_{ij}^{(y(2))}\right)^{a2} \otimes \dots \otimes \left(\check{r}_{ij}^{(y(l))}\right)^{al} =$$
$$(\left[\prod_{k=1}^{l}\left(\check{a}_{ij}^{(y(k))}\right)^{ak}, \prod_{k=1}^{l}\left(\check{b}_{ij}^{(y(k))}\right)^{ak}\right], \left[1 - \prod_{k=1}^{l}\left(1 - \check{c}_{ij}^{(y(k))}\right)^{ak}, 1 - \prod_{k=1}^{l}\left(1 - \check{d}_{ij}^{(y(k))}\right)^{ak},\right])$$
(2)

In this formula, $a = (a_1, a_2, \dots, a_l)^T$ is the weight vector for decision makers in the IVIF operator and $a_k \geq 0$. In addition, the sum of all a value must be $\sum_{k=1}^{l} a_k = 1$. Within the framework of this information, the steps of the IVIF VIKOR methodology are as follows:

Step 1. Criteria and alternatives are determined. Then, decision matrices are created from Table 3 and Table 4 within the framework of expert opinions [32].

$$\breve{\mu} = [\breve{\mu}_{ij}]_{mxn} \tag{3}$$

Table 3
Linguistic Expressions and Interval-Valued Intuitionistic Number Correspondences for Criterion Evaluation

	$\breve{\mu}_{\tilde{A}}(x), \breve{v}_{\tilde{A}}(x)$			
	μ^L	μ^U	v^L	v^U
Extremely important (EI)	0,950	1,000	0,000	0,000
Very important (VI)	0,800	0,850	0,050	0,100
important (I)	0,600	0,650	0,100	0,150
Less important (LI)	0,300	0,350	0,250	0,300
Very less important (VLI)	0,200	0,250	0,300	0,350
Extremely less important (ELI)	0,000	0,050	0,450	0,500

Table 4
Linguistic Variables Used in Alternative Rating and Interval-Valued Number Correspondences

	$\breve{\mu}_{\tilde{A}}(x), \breve{v}_{\tilde{A}}(x)$			
	μ^L	μ^U	v^L	v^L
Extremely good (EG)	0,800	1,000	0,000	0,000
Very good (VG)	0,700	0,900	0,000	0,100
Medium good (MG)	0,600	0,800	0,000	0,200
Good (G)	0,500	0,700	0,100	0,300
Approximately equal (AE)	0,400	0,600	0,200	0,400
Bad (B)	0,300	0,500	0,200	0,500
Medium bad (MB)	0,200	0,400	0,300	0,600
Very bad (VB)	0,100	0,300	0,400	0,700
Extremely bad (EB)	0,000	0,200	0,500	0,800

Step 2. At this stage, the criteria are first evaluated by decision makers according to their degree of importance. First, decision maker weights are determined. The weights of decision makers are determined based on their field of work and experience. Decision maker opinions are collected for each criterion and a decision matrix is created. The evaluations of the decision makers are combined according to the weight of each according to the calculations in Eq. (2). After this, the criterion weights are obtained with Eq. (4) and (5) below.

Weight vector $w_1, w_2, \ldots, w_n$ and $w_j \geq 0, j = 1,2, \ldots, n$, $\sum_{j=1}^{n} \breve{w} = 1$ defines the relative importance of different criteria [23].

$$w_j = \frac{1 - \breve{w}_j}{n - \sum_{j=1}^{n} \breve{w}_j} \tag{4}$$

$$\breve{w}_j = 1 - \frac{\sum_{k=1}^{K} \frac{\lambda^k (a_{ij} + b_{ij})}{2}}{\sqrt{\sum_{k=1}^{K} \frac{\lambda^k (a_{ij}^2 + b_{ij}^2 + c_{ij}^2 + d_{ij}^2)}{2}}} \tag{5}$$

Step 3. Positive ideal solution (best rating) and negative ideal solution (worst rating) values are obtained. For its benefit qualification;

$$\breve{\mu}^+ = \left(\left[(a_{ij})^+, (b_{ij})^+\right], \left[(c_{ij})^+, (d_{ij})^+\right]\right)$$

$$= \left(\left[max_i\left(a_{ij}\right)^+, max_i\left(b_{ij}\right)^+\right], \left[min_i\left(c_{ij}\right)^+, min_i\left(d_{ij}\right)^+\right]\right) \quad (6)$$

$$\breve{\mu}^- = \left(\left[\left(a_{ij}\right)^-, \left(b_{ij}\right)^-\right], \left[\left(c_{ij}\right)^-, \left(d_{ij}\right)^-\right]\right)$$

$$= \left(\left[min_i\left(a_{ij}\right)^+, min_i\left(b_{ij}\right)^+\right], \left[max_i\left(c_{ij}\right)^+, max_i\left(d_{ij}\right)^+\right]\right) \quad (7)$$

For the cost qualification;

$$\breve{\mu}^+ = \left(\left[\left(a_{ij}\right)^+, \left(b_{ij}\right)^+\right], \left[\left(c_{ij}\right)^+, \left(d_{ij}\right)^+\right]\right)$$

$$= \left(\left[min_i\left(a_{ij}\right)^+, min_i\left(b_{ij}\right)^+\right], \left[max_i\left(c_{ij}\right)^+, max_i\left(d_{ij}\right)^+\right]\right) \quad (8)$$

$$\breve{\mu}^- = \left(\left[\left(a_{ij}\right)^-, \left(b_{ij}\right)^-\right], \left[\left(c_{ij}\right)^-, \left(d_{ij}\right)^-\right]\right)$$

$$= \left(\left[max_i\left(a_{ij}\right)^+, max_i\left(b_{ij}\right)^+\right], \left[min_i\left(c_{ij}\right)^+, min_i\left(d_{ij}\right)^+\right]\right) \quad (9)$$

Step 4. To calculate the average and worst group scores, $\varphi_i\varphi_i$ and ψ_i values are obtained.

$$\varphi_i = \sum_{j=1}^{n} w_j \frac{dist\left(\left(\left[\left(a_{ij}\right)^+,\left(b_{ij}\right)^+\right],\left[\left(c_{ij}\right)^+,\left(d_{ij}\right)^+\right]\right)\left(\left[a_{ij},b_{ij}\right],\left[c_{ij},d_{ij}\right]\right)\right)}{dist\left(\left(\left[\left(a_{ij}\right)^+,\left(b_{ij}\right)^+\right],\left[\left(c_{ij}\right)^+,\left(d_{ij}\right)^+\right]\right)\left(\left[\left(a_{ij}\right)^-,\left(b_{ij}\right)^-\right],\left[\left(c_{ij}\right)^-,\left(d_{ij}\right)^-\right]\right)\right)} \quad (10)$$

$$\varphi_i = max_j \left\{ w_j \frac{dist\left(\left(\left[\left(a_{ij}\right)^+,\left(b_{ij}\right)^+\right],\left[\left(c_{ij}\right)^+,\left(d_{ij}\right)^+\right]\right)\left(\left[a_{ij},b_{ij}\right],\left[c_{ij},d_{ij}\right]\right)\right)}{dist\left(\left(\left[\left(a_{ij}\right)^+,\left(b_{ij}\right)^+\right],\left[\left(c_{ij}\right)^+,\left(d_{ij}\right)^+\right]\right)\left(\left[\left(a_{ij}\right)^-,\left(b_{ij}\right)^-\right],\left[\left(c_{ij}\right)^-,\left(d_{ij}\right)^-\right]\right)\right)} \right\} \quad (11)$$

$0 \leq w_j \leq 1,\ \sum_{j=1}^{n} w_j = 1$ represents the weight of the satisfying features and d represents the distance between IVIFN's and can be shown as follows and defined as:

$$d\left(\breve{m}_{ij}, \breve{m}_{\imath j}\right) = \sum_{k=1}^{n} w_k dist^k\left(\breve{m}_{ij}, \breve{m}_{\imath j}\right),\ w_k \in [0,1], \sum_{k=1}^{n} w_k = 1 \quad (12)$$

$w_k = (1,2,\dots,n)$, represents the weight of $d^k(\breve{m}_{ij}, \breve{m}_{\imath j})$.

Step 5. $\pi_i$ise is calculated on the equations given below, according to the results obtained from $\varphi_i\ and\ \psi_i$ values.

$$\pi_i = p\frac{(\varphi_i - \varphi^*)}{(\varphi^- - \varphi^*)} + (1-p)\frac{(\psi_i - \psi^*)}{(\psi^- - \psi^*)} \quad (13)$$

$$\varphi^* = min_i\varphi_i\ ,\ \varphi^- = max_i\varphi_i \quad (14)$$

$$\psi^* = min_i\psi_i\ ,\ \psi^- = max_i\psi_i \quad (15)$$

Smaller $\varphi_i$and ψ_i values correspond to better, average, and worse group scores for alternative a_i, respectively. The p value expresses the weight of the decision-making strategy and is evaluated based on the maximum group benefit (the majority of the attributes). Consensus can be achieved by “majority vote” ($p > 0{,}5$), “consensus” ($p = 0{,}5$) and “veto” ($p < 0{,}5$).

Step 6. Here φ^* denotes the maximum group benefit and ψ^* denotes the minimum regret of opposing decision makers. The π_i value is calculated by considering the group benefit and minimum regret and using Eq. (9). The alternatives are ranked by considering each φ^*, ψ^* ve π values in decreasing order. The result consists of a set of three sorted lists.

Step 7. At this stage, a compromise solution is determined. First, a compromise solution is tried to be determined based on π_i considering the following two conditions.

. Condition 1 (Acceptable advantage):

$$\pi(a^2) - \pi(a^1) \geq DQ \quad (16)$$

a^1 represents the first ranked alternative compared to π, and a^2 indicates the second ranked alternative. In this context, the DQ value is calculated as follows:

$$DQ = 1/(m-1) \quad (17)$$

m denotes the number of alternatives and if the number of alternatives is less than 4, DQ = 0.25.

. Condition 2 (Acceptable stability in decision making):

If the first alternative (a^1) according to π is obtained as the best alternative according to φ_i and/or ψ_i, his result is stable in the compromise solution.

If one of the above conditions is not met, the following compromise solutions are recommended:

. If the second condition is not met, although the alternative (a^1) has a superiority in the ranking, there is no stability because the rankings of $\varphi^*$and ψ^* differ. Therefore, the compromise solution of the first alternative and the second alternative is different ($\pi(a^1) = \pi(a^2)$).

. On the other hand, if the first condition is not met, that is, when $DQ > \pi(a^m) - \pi(a^1)$, compromise solutions $(a^1, a^2, \ldots, a^n)$ are accepted as similar (the positions of the alternatives are close to each other) and a^1 have no particular advantage.

4. Application

4.1. Application of IVIF-VIKOR in Defense Industry

The fact that countries have a modern armed force to increase their military power and deterrence in the international arena is proportional to the success of the projects carried out in the Defense Industry. Due to the structure of the projects carried out in this field consisting of high-cost and complex activities, the successful execution is only possible with correct and effective prioritization, which directly affects the project selection. When creating prioritization, many criteria should be evaluated from a holistic perspective and relevant projects should be ranked using scientific analytical methods.

In this context, 8 basic criteria for defense industry project prioritization are Technological Competitiveness (C_1), Domestic Sourcing (C_2), Joint Operations Compliance (C_3), Effectiveness (C_4), Lead Time (C_5), Threatening Power (C_6), Personnel Need (C_7) and The Need for Organizational Change (C_8) were determined in the literature [46].

In the first step of the method, the criteria were evaluated by 3 military experts. These evaluations were quantified with the help of Table 3 and IVIF values are included in Table 5.

Table 5
IVIF Criteria Matrix

	DM1				DM2				DM3			
C_1	0,200	0,250	0,300	0,350	0,200	0,250	0,300	0,350	0,300	0,350	0,250	0,300
C_2	0,950	1,000	0,000	0,000	0,800	0,850	0,050	0,100	0,800	0,850	0,050	0,100
C_3	0,300	0,350	0,250	0,300	0,300	0,350	0,250	0,300	0,200	0,250	0,300	0,350
C_4	0,200	0,250	0,300	0,350	0,200	0,250	0,300	0,350	0,600	0,650	0,100	0,150
C_5	0,800	0,850	0,050	0,100	0,800	0,850	0,050	0,100	0,800	0,850	0,050	0,100
C_6	0,300	0,350	0,250	0,300	0,600	0,650	0,100	0,150	0,300	0,350	0,250	0,300
C_7	0,950	1,000	0,000	0,000	0,800	0,850	0,050	0,100	0,950	1,000	0,000	0,000
C_8	0,200	0,250	0,300	0,350	0,600	0,650	0,100	0,150	0,300	0,350	0,250	0,300

Criterion weights will be obtained from the values in Table 5 using Eq. (4) and (5). When the equations are examined, the weights of the decision makers are needed. Considering their professional experience, these weights were determined as {0.40,0.35,0.25}. The criterion weights obtained as a result of the calculations are given in Figure 3.

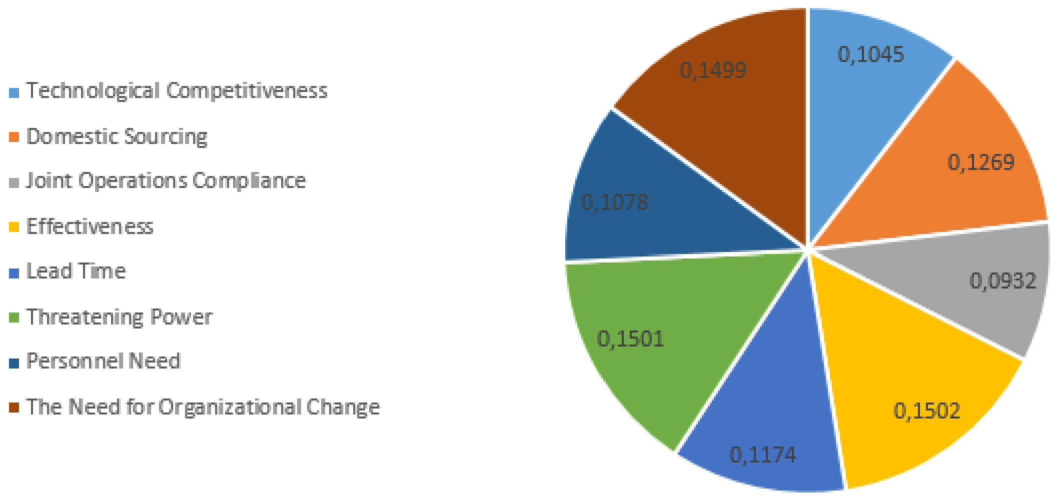

Fig. 3. Criteria Weights

Similarly, 3 military decision makers are planned generically. 4 projects were evaluated based on the determined criteria with the Table 4 and the values were digitized. Evaluations made on the basis of criteria for alternatives consist of subjective judgments. These judgments need to be combined and expressed as IVIF. Calculations using Eq. (2) are presented in Table 6.

Table 6
Collective Interval-Valued Intuitionistic Fuzzy Decision Matrix

	A_1				A_2				A_3				A_4			
C_1	0,237	0,437	0,260	0,563	0,326	0,531	0,194	0,469	0,500	0,700	0,100	0,300	0,420	0,679	0,000	0,321
C_2	0,568	0,770	0,000	0,230	0,538	0,740	0,000	0,260	0,267	0,467	0,230	0,533	0,237	0,437	0,260	0,563
C_3	0,061	0,262	0,437	0,738	0,600	0,800	0,000	0,200	0,600	0,800	0,000	0,200	0,700	0,900	0,000	0,100
C_4	0,200	0,400	0,300	0,600	0,242	0,442	0,255	0,558	0,276	0,477	0,221	0,523	0,456	0,659	0,119	0,341
C_5	0,500	0,700	0,100	0,300	0,321	0,527	0,198	0,473	0,300	0,500	0,200	0,500	0,497	0,704	0,000	0,296
C_6	0,563	0,765	0,000	0,235	0,276	0,477	0,221	0,523	0,100	0,300	0,400	0,700	0,700	0,900	0,000	0,100
C_7	0,628	0,832	0,000	0,168	0,500	0,700	0,100	0,300	0,456	0,659	0,119	0,341	0,568	0,770	0,000	0,230
C_8	0,100	0,300	0,400	0,700	0,200	0,400	0,300	0,600	0,194	0,395	0,300	0,605	0,300	0,500	0,200	0,500

Positive and negative ideal values are determined for each criterion in Table 6. Then, with the Eq. 6-9, the scores of each element's distances to the positive ideal solution and the differences between the maximum and minimum values for the score on a criterion basis are calculated. The obtained values are used in ϕ and ψ and π calculations using Eq. (10)-(12). In the last stage, a compromise solution is tried to be determined from the values in Table 7.

Table 7
Ranking Results and Parameters

	A_1	A_2	A_3	A_4
ϕ	0,5130	0,5921	0,6974	0,1725
Rank	2	3	4	1
ψ	0,1499	0,1783	0,2629	0,1269
Rank	2	3	4	1
π	0,4089	0,5884	1,0000	0,0000
Rank	2	3	4	1

In obtaining the compromise solution, the satisfaction of two conditions is examined in the evaluation made according to π. For the first condition, DQ=0.25. When Table 4 is examined, this value is calculated to be approximately 0.41. Since the calculation value is greater than 0.25, the first condition is met. Since the orders of π and ψ are the same, the second condition is also satisfied. Therefore, the solution is a compromise solution. As a result, ASM projects designated as A4 emerge as the most important project group.

5. Conclusions

Projects in the defense Industry are projects that have high budgets, take place over a long period of years, require infrastructure, and have many differences compared to other sectors in terms of their structure. Due to the high cost of such projects and the allocation of a certain amount of resources, the selection, planning, infrastructure creation, design, production and development of projects are seen as vital issues. In this process, project selection appears to be the most challenging step for decision makers. In addition, it is inevitable to consult the opinions of military decision-makers in the defense industry. For this reason, subjective judgments frequently occur. As in similar situations in decision problems in the literature, one of the FMCDM methods was used in this study.

Eight different criteria were determined using the literature for the evaluation from the defense industry perspective. When the calculation results of the criterion weights are examined, the order of importance of the criteria is similar to the study by Kurtay et al. [46]. Then, an approach consisting of the integration of IVIFS and VIKOR method was applied to make selection in the alternative group consisting of land, air, SAM and ASM projects. When the steps of the methodology are applied, ASMs emerge as the most important project group. Although land wars seem to be in the background, evaluations of military decision makers show that land projects are in the second group. Then, air and SAM projects are listed. These rankings consider the experiences of military experts and they can be flexibly recalculated to meet different needs or views.

Since this study is presented as a model proposal on generic projects, it can be easily applied to situations with different numbers of criteria and projects and can provide accurate, consistent and effective decision support to decision makers. The findings obtained are limited to the results obtained from the applied method since a single MCDM method was used in the study. In case the number of methods is increased or different methods are applied other than the applied method, the results may evolve into different situations. In future studies, more comprehensive and detailed results can be obtained by including more criteria and sub criteria in the model and analyzing them with different MCDM methods.

Conflicts of Interest
The author declare no conflicts of interest.

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