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Unmanned aerial vehicle selection using interval valued q rung orthopair fuzzy number based MAIRCA method

Aralık değerli q seviyeli bulanık sayı temelli MAIRCA yöntemiyle insansız hava aracı seçimi

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Abstract

This study proposes an extended version of MAIRCA (MultiAtributive Ideal-Real Comparative Analysis) for unmanned aerial vehicle (UAV) selection using the interval valued q rung orthopair fuzzy (IVqROF) number. Firstly, the opinions of three experts were sought regarding the selection of UAV. 10 criteria and 4 alternatives were determined for UAV selection. Experts expressed their opinions using linguistic variables, and these linguistic variables were converted into IVqROF numbers. For criteria weights, the opinions of 3 experts were converted to group opinion using the aggregation operator. A similar process was carried out for 4 alternatives based on 10 criteria. This study proposed a new approach to the literature by examining the number of IVqROFs in the MAIRCA method. It also proposes a new model for the field of UAV selection. IVqROF number ensures more advantages than other fuzzy numbers such as intuitionistic fuzzy number and the Pythagorean fuzzy number as it can adjust the restriction on the membership and non-membership degrees in evaluating the judgments of the experts.

Keywords: Interval valued q-rung orthopair fuzzy number, MAIRCA method, Multi criteria decision making, Unmanned aerial vehicle.

Öz

Bu çalışma insansız hava aracı seçimi için aralık değerli q seviyeli bulanık (ADqSB) sayı temelli MAIRCA (MultiAtributive Ideal-Real Comparative Analysis) metodunu yeni bir yaklaşım olarak literatüre sunmaktadır. Çalışmada üç kişiden oluşan bir uzman grup insansız hava aracı için 10 kriter ve 4 alternatif belirlemişlerdir. Uzmanlar dilsel değişkenler kullanarak görüşlerini belirtmiş daha sonra bu dilsel değişkenler ADqSB sayıya çevrilmiştir. Birleştirme operatörü kullanılarak üç uzmanın görüşünden grup görüşü elde edilmiştir. Kriter ağırlıkları bulunurken birleştirme operatörü kullanılmıştır. Benzer işlemler 10 kriter temelli 4 alternatif için de gerçekleştirilmiştir. Bu çalışma MAIRCA metodunun yeni versiyonunu önermesi ve insansız hava aracı seçimi için yeni bir yaklaşım önermesinden dolayı literatürdeki çalışmalardan farklılık göstermektedir. ADqSB sayı, uzman görüşlerini değerlendirmede ait olma ve ait olmama derecelerindeki kısıtlamayı ayarlayabildiği için sezgisel bulanık sayı ve Pisagor bulanık sayı gibi bulanık sayılara göre daha fazla avantaj sağlamaktadır.

Anahtar kelimeler: Aralık değerli q seviyeli bulanık sayı, MAIRCA metodu, Çok kriterli karar verme, İnsansız hava aracı.

1 Introduction

Illegal activities such as terrorist acts, irregular migration and smuggling are very common around the world. Preventing these activities and protecting geographical borders is very important for countries. At the same time, as the development of technology has gained momentum, it is important that this development be adapted to technological warfare tools used for military purposes. In recent years, it has been observed that a large portion of countries' economic budgets are spent on defense industry, which is one of the most important expenditure items. It is necessary to decide which evaluation criteria will be used and adapted to decision support processes in order to produce technologies that will support the defense industry and reduce foreign dependency within the country, to evaluate the produced technologies within the army, and to add them to the inventory in cases where it is not possible to produce them with domestic means. Interventions by the security forces of countries to prevent activities such as terrorist acts, irregular migration and smuggling and to protect geographical borders will be more effective by using technological means rather than manpower, it will be possible to prevent the loss of trained people and to use economic resources more effectively.

UAVs have some advantages over traditional manned systems. These can be stated as follows [1]-[2]:

- *Lower purchasing and operating costs,
- Not being affected by physiological factors, opportunity to fly for longer and more frequent periods,
- Ability to be quickly directed to another task while in the air,
- Minimizing the risks and error rates that may occur due to human factors and providing maximum benefit in tasks requiring high precision,
- The opportunity to perform the task in hazardous and chemical risk environments by eliminating the possibility of crew loss,
- There is no risk of death to people during an accident.

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One of the tools that can perform the mentioned interventions most effectively in today's technology is unmanned aerial vehicles. UAVs help implement today's modern warfare methods. UAVs are on their way to becoming very useful, economical combat vehicles that can create surprise effects on the battlefield and have the potential to be indispensable for the future [3]. In our country, as well as in all countries of the world, efforts to transform war vehicles into domestic and national technology support both the increasing interest in UAV technology and the increase in the security of our land, air and seas as domestic and national projects of this technology. UAV has developed rapidly since the early 2000s, while the number and types of systems used have increased, its capabilities have also improved greatly and it has brought a new understanding to ensure military security. The ability of the armed forces to carry out their intervention, reconnaissance, border protection and surveillance duties in an active, deterrent and effective manner depends on the military equipment and technologies in their inventory being up-to-date and new, and their selection and planning using scientific methods. Countries can improve their military strength and resilience with a strong defense industry in the world order, thus supporting national security and stability. Nations with strong defense industries and armies also find political power in themselves. At the same time, the use and maintenance of these developed technologies contribute to countries as economic power. The more efficient use of unmanned aerial vehicles compared to other manned systems makes the choices to be made in this field even more critical.

The processes of examining, selecting, and supplying combat vehicles that can meet the needs in developing technology are among the strategically important decisions. The process of ensuring that the technological tool decided on contributes to the inventory for many years and is used successfully in the tasks it will undertake should be evaluated at the maximum efficiency level. At the same time, since these technology systems are quite costly and complex, they are technologies for which a significant proportion should be allocated from the defense industry expenditure budget for the country's economy. For this reason, during the selection process of such advanced military technologies, many criteria must be examined in detail at the same time, the alternatives must be determined correctly, expert opinions and decision makers must be impartial and reliable data must be obtained, and these data must be transferred to the decision system. In such selection processes, many different decision-making methods are used to ensure success in making the right decision. Especially when we look at the past years, traditional multi-criteria decision making (MCDM) methods, which allow evaluation by taking many criteria into consideration, are frequently used.

In this study, UAVs will be prioritized using criteria such as useful load, operational altitude, air residence time, operational speed. All criteria are presented in Table 1. The optimal technological combat vehicle that will provide maximum benefit will be selected by creating a decision model with the MAIRCA (MultiAtributive Ideal-Real Comparative Analysis) method using interval-valued q-rung orthopair fuzzy (IVqROF) numbers.

Although fuzzy sets are very successful in evaluating uncertainties, they are insufficient in explaining the degree of non-membership/hesitancy of decision makers. In order to fill this deficiency of fuzzy sets, Atanassov presented an intuitionistic fuzzy set model in which both membership and non-membership degrees can be evaluated [4]-[5].

Pythagorean fuzzy sets, which are considered an extension of intuitionistic fuzzy set models, were introduced as a result of the need for a wider definition range. In an intuitionistic fuzzy set, the sum of the membership and non-membership degrees is allowed to be at most 1, and if it is less than 1, the difference is defined as hesitancy. In Pythagorean fuzzy sets, the sum of the squares of the membership and non-membership degrees is allowed to be at most 1 for a wider definition range. However, Pythagorean fuzzy sets are also lacking in some real applications. In order to achieve more accurate results in these real practices, a generalized q-ROF sets model can adjust the restriction on membership and non-membership degrees from a parameter type as an extension of Pythagorean fuzzy sets [5].

The study consists of five main headings in total. In the first part, after an introduction explaining the importance of UAVs and why they should be used, information is given about the definitions, classifications, UAV components and history of unmanned aerial vehicles, and the advantages and disadvantages of their use in the military field. Additionally, in the first section, information about the topics of the paper is included. After introducing UAVs in general terms, in the second part, a literature review was made and examined in two separate parts. In the first part, studies on UAV and military equipment selection using MCDM methods were examined. In the second part, a literature review of the criteria, alternatives and selection of the methods used in publications using the fuzzy MAIRCA method was conducted. In the third section, information is given about the method that will be the subject of the study. In the fourth section, the problem was introduced by sharing the values of the alternatives and criteria created by taking expert opinions, and the final result of the problem was obtained by applying the solution steps. In the last section, the conclusion, comments were made on the ranking scale found as a result of the application of the established model.

2 Literature review

In the literature review in this study, the technologies used in the military field and the multi-criteria decision-making methods determined as the solution method for UAV selection were examined, and then the studies on the method to be used in the study were examined. When the methods used as a result of the literature review are examined, it is seen that classical MCDM methods have been used quite frequently. In the following years, MCDM methods were developed and many new methods were introduced to decision processes. MCDM methods are implemented for different areas such as polymeric material selection [6], thermoplastic material selection [7], manufacturing process selection [8].

Cheng (1997) examined the tactical missile systems used for the military navy using the fuzzy AHP (Analytical Hierarchy Process) method. While making this evaluation, 3 alternative missile systems were evaluated based on 5 criteria. As a result of the evaluation, the best missile system was selected among the alternatives for the purpose of the study [9]. Cheng et al. (1999) worked to choose the best attack helicopter among 3 alternatives. In the selection stages, 5 basic criteria and 3 alternative attack helicopters were evaluated subjectively together with the linguistic variables by establishing a relationship with the linguistic variables. The best choice among the alternatives was obtained by using the AHP method [10].

Table 1. Criteria and expressions.

Abbreviation	Criteria	Studies handling the criteria	Explanation
CRI1	Useful Load	[12]-[14],[16]	These are equipment that vary depending on the mission the aircraft will perform.
CRI2	Operational Altitude	[12]-[14],[16]	It is the altitude that the aircraft can ascend during the mission.
CRI3	Air Residence Time	[12]-[14]	It is the criterion that expresses how long the UAV can perform its mission before returning to its base.
CRI4	Operational Speed	[12],[13],[16]	It is the criterion used instead of the maximum speed of the UAV to enable it to shoot more accurately while performing its mission.
CRI5	Wingspan	[12],[13],[15],[16]	Wingspan, which will directly affect maneuverability, is considered a critical criterion.
CRI6	Reliability	[12]	It is the criterion that includes the security of the software systems used in the aircraft.
CRI7	Operational Capability	[13],[16]	Considering that the task is to protect the borders and intervene when necessary, operational capability is one of the most important criteria.
CRI8	Developability	[12]	It is the criterion that expresses the level of adaptation of the aircraft to new technologies.
CRI9	Autonomy	[12]	It is the criterion that expresses the level of autonomous use of the aircraft.
CRI10	Pre-Flight Maintenance Period		It is the criterion that expresses how much time is spent preparing the aircraft for flight.

Wang and Chang (2007) conducted a study on determining the first training aircraft to be selected for the Taiwan Air Force inventory. 16 criteria were determined to be evaluated by taking the opinions of 15 expert personnel working at the Taiwan Air Force Academy. In this study, the fuzzy TOPSIS method, which responds to subjective values and parameterized expressions, was used to determine the highest performance value among 7 alternative aircrafts [11].

Özge (2009) handled the problem of UAV selection for use in internal security operations was solved. During the selection phase, 6 basic criteria and 25 sub-criteria were determined and the weights of each were determined with the help of pairwise comparisons. The selection was made using AHP, one of the MCDM methods. Among the 5 alternatives, the most optimum alternative UAV was chosen to be used in internal security operations [12].

Kuo-Ping Lin et al. (2011) developed a program using a computer-based and fuzzy weighted average method for UAV selection for use in the field to meet military needs. With this developed interface, this computer-based method has enabled decision makers to more easily reach the most effective result in the decision-making process, compared to previously used methods [13].

Ulucan (2016) chose a UAV to be used for civil and military purposes. During the determination of alternatives, the actively used systems were simulated and 4 alternatives were obtained intuitively. 10 criteria were determined using expert opinions and the Delphi method. During the solution of the problem, Gray Relational Analysis, one of the MCDM methods, was used to include uncertainties in the problem and sorting was done in order to obtain a better solution [14].

Büyükesen (2021) examined the effects of design parameters for the flight safety of UAV. The study performed a flight safety analysis using different design parameters of 11 UAVs [15]. Hamurcu et al. (2020) considered the selection of UAVs for defense purposes using AHP and TOPSIS methods, one of the MCDM methods. 6 UAV alternatives and 7 criteria that will have a direct impact on the selection were determined, and 7 criteria were weighted with the help of pairwise comparisons. By solving the obtained weighted criteria, the best UAV was selected among the alternatives [16].

While scanning the literature, studies using the fuzzy MAIRCA method, which has been the subject of studies in the past years, were mentioned. In these studies, the results obtained from several fuzzy MCDM methods are generally calculated and compared with each other.

Pamučar (2019) developed a method that enables decision-making using only internal information obtained from data, using objective uncertainty to eliminate uncertainty and imprecision based on interval-valued fuzzy numbers (IVFN). This model, used in conjunction with the classical MAIRCA method, selects the most suitable landing point to overcome water obstacles. Sensitivity analysis of the IVFN based MAIRCA model was carried out over 24 scenarios, showing that the results have a high degree of stability [17].

Boral et al. (2020) ranked the failure modes integrating fuzzy AHP and fuzzy MAIRCA methods. The geometric mean approach was used to calculate the relative importance between risk factors. The fuzzy MAIRCA approach has been proposed to calculate the difference between real and theoretical values [18]. Efe and Efe (2023) handled qROF number based MAIRCA approach for emergency service selection of patients [19]. Supçiller and Öktem (2023) focuses on fuzzy CRITIC and fuzzy MAIRCA methods for extruder line selection [20].

Ecer et al. (2022) aimed to determine the most suitable crypto currencies for investment. Fifteen well-known cryptocurrencies with the highest market capitalization were evaluated based on sixteen factors. The highlight of the study is a group decision making process for cryptocurrency selection using an intuitive fuzzy set-driven methodology that includes Distance-Based Assessment from Average Solution (EDAS), Multi-Attribute Ideal Real Comparative Analysis (MAIRCA), and Measurement and Ranking of Alternatives by Consensus Solution (MARCOS) were applied to provide the mechanism and listed the alternatives [21].

Ecer (2022) developed a new heuristic called MAIRCA framework's heuristic fuzzy MAIRCA (SB-MAIRCA) to evaluate 5 different vaccines approved by world health authorities using criteria such as duration of protection, effectiveness of vaccines developed for the COVID-19 virus, success against mutations and logistics suggest the fuzzy extension. In this study, within the framework of SB-MAIRCA, based on the decision making of the group, both criterion weights were obtained and the priority order of alternatives under uncertainty was determined [22].

Fetanat and Tayebi (2023) chose industrial filtration technologies for pollution control in a natural gas processing facility. The q-rung orthopair fuzzy set-based MAIRCA method was used as the method in the study. In the study conducted using 18 criteria and 5 alternatives, the priority order was obtained from the most preferred alternative to the least preferred alternative [23]. Recent studies focused on qROF numbers in different areas such as risk assessment [24], product design [25].

In this study, 10 criteria were determined for UAV selection. Opinions were collected from three experts on the importance levels of the criteria by using an interval-valued q-rung orthopair fuzzy number. A group view was obtained through the join operator. Then, four UAV alternatives were examined based on 10 criteria, in line with the opinions of three experts. For the ranking of alternatives, the interval-valued q-rung orthopair fuzzy number-based MAIRCA method was used. In the literature, the q-rung orthopair fuzzy number-based MAIRCA method has been examined in only one study by Fetanat and Tayebi [23]. Unlike the study of Fetanat and Tayebi [23], in this study, the interval-valued q-rung orthopair fuzzy MAIRCA method was examined and a new method was introduced to the literature. In addition, the developed method was applied to UAV selection and a new method was presented to the current application field.

3 The proposed method

Interval valued q-rung orthopair fuzzy logic based MAIRCA (MultiAtributive Ideal-Real Comparative Analysis) method was used to select the best UAV among the alternative UAVs according to the determined criteria. MAIRCA method, which is one of the methods that Gigoviç et al. (2016) worked on and introduced to the literature as the MCDM method, is defined as a method that expresses the gaps between ideal and experimental evaluations. By collecting the gaps for each criterion separately and then calculating the total gaps of the decision alternatives, the alternative with the lowest total gap value is evaluated as the best result in the ranking [26]-[27].

Although the MAIRCA method has an algorithmic structure that seems simple when looked at superficially from a mathematical perspective, there is no problem in using it simultaneously with multi-criteria decision-making methods and the reliability of the results. At the standardization level of the MAIRCA method, the linear normalization method is used. It has been determined that the ranking results obtained in studies conducted with this method give more consistent and reliable results than other MCDM methods. It impartially gives equal chances to each of the alternatives evaluated in the initial stage of the method; In the following steps, as a result of evaluating the alternatives according to the criteria in the evaluation system, the equivalent chance situations given in the initial stage disappear on their own, and subsequently the alternatives become different from each other and can be distinguished [28].

Originally proposed by Yager, q-rung orthopair found sets were explained as a way to represent uncertain information. The aim is to provide a compromise solution with maximum benefit and minimum individual regret to solve MCDM problems with the q-rung orthopair MAIRCA method. With the interval-valued q-rung orthopair MAIRCA method, it makes it easier for the decision maker to express the membership degrees in clear numbers in case of inadequacy in the existing information. With this proposed method, it can be used very effectively to solve problems that carry uncertainty data and do not have definitive results [23],[29].

This section presents the steps of MAIRCA method and definitions of interval valued q-ROF number.

3.1 MAIRCA method

The steps of the MAIRCA method are summarized below [30].

Step 1: Establishing the decision matrix. The criterion (Cj) values for each alternative (Ai) are included in Equation (1):

$$x = \begin{array}{c} \begin{matrix} C_1 & C_2 & \dots & C_n \end{matrix} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m1} & \cdots & x_{mn} \end{bmatrix} \end{array} \quad (1)$$

Step 2: It is essential for the decision maker to be impartial. While m is the total number of alternatives, the priority of ith alternative (PAi) is calculated with the help of Equation (2). Since the decision maker is equidistant from each of the alternatives, all priorities are equal as in Equation 3:

$$P_{A_i} = \frac{1}{m}; \sum_{i=1}^{m} P_{A_i} = 1 \quad i = 1,2,3, \dots m \quad (2)$$

$$P_{A_1} = P_{A_2} = \dots = P_{A_m} \quad (3)$$

Step 3: Establishing of the matrix of theoretical ponder. $tpij$ matrix is found by multiplying the priorities of the alternatives (PAi) with weights the criteria (wj). It is presented in Equation (4):

$$T_p = \begin{bmatrix} P_{A1} * W_1 & P_{A1} * W_2 & \cdots & P_{A1} * W_n \\ P_{A2} * W_1 & P_{A2} * W_2 & \cdots & P_{A2} * W_n \\ \vdots & & \ddots & \vdots \\ P_{Am} * W_1 & P_{Am} * W_2 & \cdots & P_{Am} * W_n \end{bmatrix} \quad (4)$$

Step 4: The matrix of real ponder (Tr) matrix is obtained by making use of the Tp matrix and X matrix. Matrix elements are calculated with the help of Equation (5) for maximization type criteria and Equation (6) for minimization type criteria:

$$t_{rij} = t_{pij} \times \left(\frac{x_{ij} - x_{ij}^-}{x_{ij}^+ - x_{ij}^-} \right) \quad (5)$$

$$t_{rij} = t_{pij} \times \left(\frac{x_{ij} - x_{ij}^+}{x_{ij}^- - x_{ij}^+} \right) \quad (6)$$

x_{ij}^+ shows the maximum value getting from alternative ($x_{ij}^+ =$ max $(x_1, x_2, \dots, x_m)$, x_{ij}^- shows the minimum value getting from alternative ($x_{ij}^- =$ $(x_1, x_2, \dots, x_m)$.

Step 5: The total gap matrix (TG) is obtained by subtracting the matrix of real ponder (Tr) from the matrix of theoretical ponder (Tp) with the help of Equations (7)-(8):

$$G_{ij} = tp_{ij} - tr_{ij} \tag{7}$$

$$TG = T_P - T_R \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ g_{m1} & g_{m2} & \cdots & g_{mn} \end{bmatrix} \tag{8}$$

Step 6: In the last step of the method, the sum of the criterion values in TG matrix is found separately for each alternative with the help of equation (9). The alternative with the smallest value among the values obtained from this equation is considered the best alternative. Equation (9) is presented as follows:

$$Q_{\mathrm{i}} = \sum_{j=1}^{n} g_{ij} \quad i = 1,2,3,\ldots m \tag{9}$$

3.2 Interval valued q-ROF number

Yager [31] proposed the q-ROF number to overcome the shortcomings of the intuitionistic fuzzy number and the Pythagorean fuzzy number. Interval valued q-ROFN (IVq-ROFN) whose definition is given below, has been proposed by expanding q-ROF numbers. Ju et al. [29] defined IVq-ROFN operators below.

Definition 1: Let X be a non-empty fixed set, an IVq-ROFN on X can be defined in Equation (10):

$$A = \{< \mathrm{x}, ([\mu_A^L(x), \mu_A^U(x)], [\vartheta_A^L(x), \vartheta_A^U x]) > | x \in X\} \tag{10}$$

$[\mu_A^L(x), \mu_A^U(x)]$ and $[\vartheta_A^L(x), \vartheta_A^U x]$ show the membership and non-membership degrees for $x \in X$ in set A, respectively. It must be ensured $x \in X$: $[\mu_A^L(x), \mu_A^U(x)] \subseteq [0,1]$, $[\vartheta_A^L(x), \vartheta_A^U(x)] \subseteq [0,1]$, $(\mu_A^U(x))^q + (\vartheta_A^U(x))^q \leq 1$ conditions.

$[\pi_A^L(x), \pi_A^U(x)]$=$\left[(1 - (\mu_A^U(x))^q - \left(\vartheta_A^L(x)\right)^q)^{\frac{1}{q}}, (\mu_A^L(x))^q - \left(\vartheta_A^L(x)\right)^q)^{\frac{1}{q}}\right]$ shows the hesitancy of $x \in X$.

$[\mu_A^L(x), \mu_A^U(x)]$, $[\vartheta_A^L(x), \vartheta_A^U(x)]$ is shown as $a = [\mu_a^L, \mu_a^U]$, $[\vartheta_a^L, \vartheta_a^U]$ to ensure the convenience.

Definition 2: Let be $a_1 = [\mu_1^L, \mu_1^U], [\vartheta_1^L, \vartheta_1^U]$ and $a_2 = [\mu_2^L, \ \mu_2^U]$, $[\vartheta_2^L, \vartheta_2^U]$ two IVq-ROFNs. Some mathematical operations are presented in Equations (11)-(14):

$$\begin{aligned} a_1 \oplus a_2 = {} & \left[((\mu_1^L)^q + (\mu_2^L)^q - (\mu_1^L)^q \times (\mu_2^L)^q))^{1/q}, ((\mu_1^U)^q \right. \\ & \left. + (\mu_2^U)^q - (\mu_1^U)^q \times (\mu_2^U)^q))^{1/q} \right], [(\vartheta_1^L) \\ & \times (\vartheta_2^L), (\vartheta_1^U) \times (\vartheta_2^U)] \end{aligned} \tag{11}$$

$$\begin{aligned} a_1 \otimes a_2 = {} & [(\mu_1^L) \times (\mu_2^L), (\mu_1^L \times (\mu_2^L)], \\ & \left[((\vartheta_1^L)^q + (\vartheta_2^L)^q - (\vartheta_1^L)^q \right. \\ & \times (\vartheta_2^L)^q)^{1/q}, ((\vartheta_1^U)^q + (\vartheta_2^U)^q - (\vartheta_1^U)^q \\ & \left. \times (\vartheta_2^U)^q)^{1/q} \right] \end{aligned} \tag{12}$$

$$\begin{aligned} \lambda a_1 = {} & \left[(1 - (1 - (\mu_1^L)^q)^\lambda)^{1/\mathrm{q}}, (1 - (1 - (\mu_1^U)^q)^\lambda)^{1/\mathrm{q}}, \right. \\ & \left. \left[(\vartheta_1^L)^\lambda, \quad (\vartheta_1^U)^\lambda\right]\right], \lambda > 0 \end{aligned} \tag{13}$$

$$\begin{aligned} {a_1}^\lambda = {} & \left[(\mu_1^L)^\lambda, (\mu_1^U)^\lambda\right], \left[(1 - (1 - (\vartheta_1^L)^q)^\lambda)^{1/q}, (1 - \right. \\ & \left. (1 - (\vartheta_1^U)^q)^\lambda)^{1/q}\right], \lambda > 0 \end{aligned} \tag{14}$$

Definition 3: If $a = [\mu_a^L, \mu_a^U], [\vartheta_a^L, \vartheta_a^U]$ is an IVq-ROFN, score function $S(a)$ and accuracy function $P(a)$ are defined in Equations (15)-(16):

$$S(a)=\frac{1+(\mu_a^U)^q-(\vartheta_a^U)^q+1+(\mu_a^L)^q-(\vartheta_a^U)^q}{4} \tag{15}$$

$$P(a)= \frac{(\mu_a^U)^q-(\mu_a^L)^q+(\vartheta_a^U)^q-(\vartheta_a^U)^q}{4} \tag{16}$$

For 0≤ S(a)≤1, the higher the S(a) score point, the higher the IVq-ROFN will be. If S(a)=1 then a=[1,1],[0,0]; if S(a)=0 then a=[0,0],[1,1]. Likewise, for 0≤ P(a)≤1, the higher the P(a) score, the higher the IVq-ROFN will be. The score function is used to rank fuzzy numbers.

Definition 4: IVq-ROFNs $(a_{1,} a_{2,} \ldots, a_n)$ can be combined by using geometric mean aggregation operator. This operator, which is used to aggregate the opinions of the experts, is presented in Equation (17):

$$\begin{aligned} & [\mu^L(x), \mu^U(x)], [\vartheta^L(x), \vartheta^U(x)] \\ & = \langle \left[\prod_{j=1}^{n} (\mu_j^L)^{w_j}, \prod_{j=1}^{n} (\mu_j^U)^{w_j}\right], \\ & \left[(1 - \prod_{j=1}^{n} \left(1 - (\vartheta_j^L)^q\right)^{W_j})^{1/q}, (1 \right. \\ & \left. - \prod_{j=1}^{n} \left(1 - (\vartheta_j^U)^q\right)^{W_j})^{1/q}\right] \rangle \end{aligned} \tag{17}$$

Definition 5: If $a_1 = ([a_1, b_1], [c_1, d_1])$ and a_2= $([a_2, b_2], [c_2, d_2])$ are two IVq-ROFNs, the distance among them is calculated by using Equation (18):

$$\begin{aligned} d(a_1, a_2) = {} & \frac{1}{4}\left(|a_1^2 - a_2^2| + \left|b_1^2 - b_2^b\right| + |c_1^2 - c_2^2| \right. \\ & \left. + |d_1^2 - d_2^2|\right) \end{aligned} \tag{18}$$

4 Application and results

The equations related to interval-valued q-rung orthopair fuzzy sets that we will use as the solution to our problem are expressed in detail under the heading of methods. In this section, the criteria and alternatives we will use during the implementation phase are defined and the professional characteristics of the experts are introduced. The criteria used are tabulated in Table 1. When past studies for UAV selection were examined, although criteria such as communication range, communication capability, aircraft operating cost and interoperability were used in addition to the criteria we will use, it was predicted that the ten criteria determined as a result of interviews with expert personnel would be sufficient for the problem. A selection problem will be created among the alternatives with the help of criteria and the optimum one will be selected among the alternatives with matrix solutions. The flowchart of the proposed method is presented in Figure 1.

The UAVs determined as alternatives were selected from the systems that are currently actively used in the mission areas and the alternatives were included in the problem as alternative 1, alternative 2, alternative 3 and alternative 4. The opinions of 3 expert military personnel who continue to work actively in their field were consulted in the matrices to be created during the solution stages. Expert 1 is a senior officer with 25 years of experience and experience who has worked in military factories. Expert 2 is a senior officer who is an engineer and has previously served in the Land Forces Command.

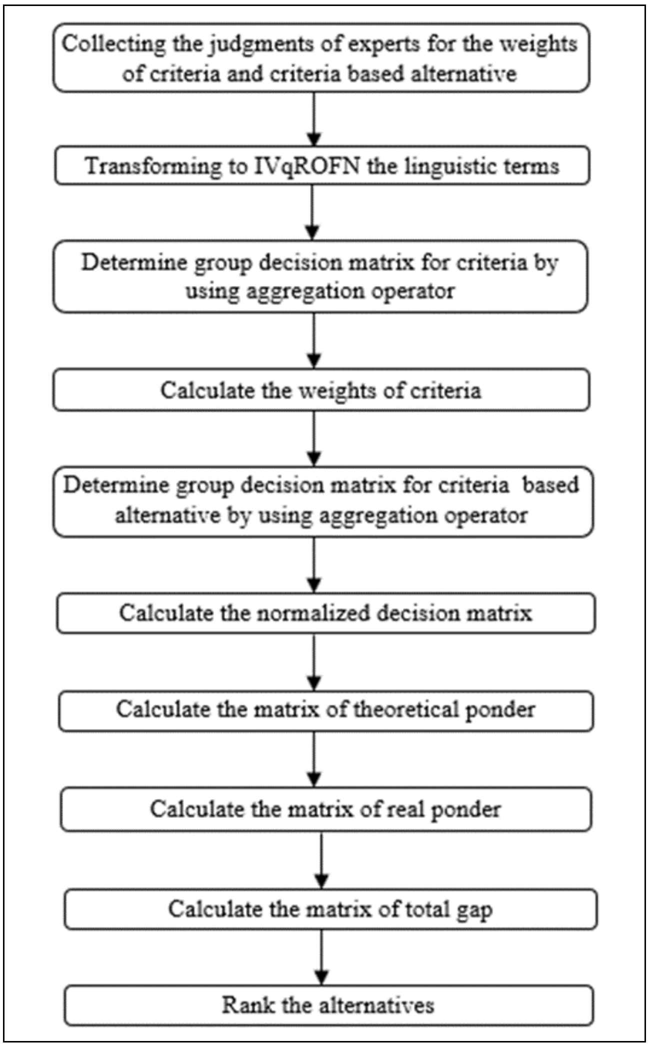

Figure 1. The flowchart of the proposed method.

Expert 3 is a personnel who worked at the National Defense University Military Academy and took part in many military projects. The opinions collected from three experts were included as expert opinions in the problem solution, and then the importance levels of the criteria were determined by the experts. Primarily, linguistic variables were used when consulting expert opinions. Table 2 shows the linguistic variables used in the evaluation of alternatives and their fuzzy number equivalents.

Three experts were asked to evaluate each of the criteria separately for the criteria and alternatives. As a result of these evaluations, in line with the information obtained from the experts, the linguistic expert opinions for the criteria are given in Table 3, and the linguistic opinions of 3 experts for all the criteria for each alternative are given in Table 4.

In the table given in Table 5, the fuzzy number values given as the lower and upper values calculated by taking q=3 in Table 4 are recorded as the degree of importance for each criterion for three experts. Linguistic expert opinions given for the criteria will be converted into numerical data starting from Table 5 and will be used to calculate the matrices that will be created in the other steps.

Afterwards, the criterion weights were calculated using the geometric averages of the lower and upper values for the criteria we obtained in Table 5. Common opinions of common experts as lower and upper values are tabulated as criterion weights in Table 6. Expert opinions were used for criteria based alternatives and a combined group decision matrix table was formed, in which the common opinions of three experts were obtained. Table 7 presents the weighted normalized decision matrix.

The theoretical rating matrix was obtained by multiplying the priorities of the alternatives and the criterion weights. The obtained results are tabulated in Table 8.

The matrix of real ponder in Table 9 was obtained by using the theoretical rating matrix and the initial decision matrix. Theoretical ponder matrix and real ponder matrix were used to obtain the total gap matrix in Table 10.

B_i values are listed from smallest to largest and the ranking of the alternatives is revealed. The decision alternative with the lowest B_i value was determined as the best alternative. B_i values and rankings of the alternatives are given in Table 10.

Alternative 2 was determined as the best alternative. Other rankings were found as A1, A3 and A4 respectively. A sensitivity analysis is examined the impact of changing the weights of criteria and the result is shown in Table 11.

K3-K7 means that the original weights of K3 and K7 criteria are replaced each other in the examined sensitivity analysis. The orders of the first and second alternatives don't change except K1-K4 scenario. It is normal because the difference between the original weights of K1 and K4 criteria is very big. This difference can change the ordering. The third and fourth alternatives are more affected by different scenarios. This is neglected because the most important thing of UAVs selection is the order of the first and second alternative. Table 12 presents a comparison analysis. The proposed method is compared with classic MAIRCA, VIKOR and TOPSIS methods. The results of the proposed method and classic MAIRCA are the same. The results of the proposed method, classic VIKOR and TOPSIS are the same except A3 and A4. This shows that the proposed method is useful for UAV selection problem.

Table 2. Numerical reciprocals of linguistic variables.

Linguistic terms		
Very high (VH)	[(0.95, 0.99),	(0.20, 0.30)]
High (H)	[(0.80, 0.90),	(0.30, 0.40)]
Few high (FH)	[(0.60, 0.70),	(0.40, 0.50)]
Medium (M)	[(0.50, 0.60),	(0.50, 0.60)]
Few low (FL)	[(0.30, 0.40),	(0.70, 0.80)]
Low (L)	[(0.20, 0.30),	(0.90, 0.95)]
Very low (VL)	[(0.10, 0.20),	(0.96, 0.99)]

Table 3. Expert opinions for criteria.

Criteria	Expert 1	Expert 2	Expert 3
CRI1	VH	FH	H
CRI2	M	H	H
CRI3	H	VH	VH
CRI4	FL	M	L
CRI5	VL	L	VL
CRI6	M	FL	M
CRI7	H	FH	VH
CRI8	FL	M	L
CRI9	M	FH	H
CRI10	L	FL	FL

Table 4. Expert opinions for alternatives.

	Alternative	CRI1	CRI2	CRI3	CRI4	CRI5	CRI6	CRI7	CRI8	CRI9	CRI10
Expert 1	UAV1	H	M	VH	FL	L	FL	VH	FL	FH	FL
	UAV2	VH	FH	H	M	VL	H	H	L	L	VL
	UAV3	FH	FL	FH	L	M	FH	VH	L	H	M
	UAV4	FH	H	H	L	FH	VH	M	M	VH	L
Expert 2	UAV1	M	VH	FH	FH	L	H	FL	FL	VH	L
	UAV2	H	FH	H	VL	VL	M	H	H	FH	FL
	UAV3	FH	H	FL	FL	M	FH	VH	VH	L	M
	UAV4	H	M	FH	M	VL	L	VH	M	FL	FH
Expert 3	UAV1	FH	VH	H	FL	VL	M	FH	H	M	L
	UAV2	H	FH	VH	M	L	FH	H	FL	VH	FL
	UAV3	VH	M	FH	L	FL	H	VH	M	L	VL
	UAV4	M	L	VH	FH	L	VH	M	FH	FL	M

Table 5. The importance degrees of criteria.

Criteria	CRI1	CRI2	CRI3	CRI4	CRI5
Weights	[(0.7697, 0.8544), (0.3217,0.4177)]	[(0.6840, 0.7862), (0.3933,0.4901)]	[(0.8971, 0.9590), (0.2431,0.3405)]	[(0.3107, 0.4160), (0.7730,0.8530)]	[(0.1260, 0.2289), (0.9461,0.9830)]
Criteria	CRI6	CRI7	CRI8	CRI9	CRI10
Weights	[(0.4217, 0.5241), (0.5894,0.6915)]	[(0.7697, 0.8544), (0.3217,0.4177)]	[(0.3107, 0.4160), (0.7730,0.8530)]	[(0.6214, 0.7230), (0.4177,0.5159)]	[(0.2621, 0.3634), (0.7994,0.8777)]

Table 6. The aggregated group decision matrix.

	UAV1	UAV2	UAV3	UAV4
CRI1	[(0.6214, 0.7230), (0.4177, 0.5159)]	[(0.8472, 0.9291), (0.2746, 0.3728)]	[(0.6993, 0.7857), (0.3575, 0.4538)]	[(0.6214, 0.7230), (0.4177, 0.5159)]
CRI2	[(0.7670, 0.8378), (0.3650, 0.4556)]	[(0.6000, 0.7000), (0.4000, 0.5000)]	[(0.4932, 0.6000), (0.5605, 0.6618)]	[(0.4309, 0.5451), (0.7285, 0.8086)]
CRI3	[(0.7697, 0.8544), (0.3217, 0.4177)]	[(0.8472, 0.9291), (0.2746, 0.3728)]	[(0.4762, 0.5809), (0.5520, 0.6540)]	[(0.7697, 0.8544), (0.3217, 0.4177)]
CRI4	[(0.3780, 0.4820), (0.6388, 0.7412)]	[(0.2924, 0.4160), (0.8217, 0.9032)]	[(0.2289, 0.3302), (0.8599, 0.9225)]	[(0.3915, 0.5013), (0.7334, 0.8139)]
CRI5	[(0.1587, 0.2621), (0.9268, 0.9710)]	[(0.1260, 0.2289), (0.9461, 0.9830)]	[(0.4217, 0.5241), (0.5894, 0.6915)]	[(0.2289, 0.3476), (0.8845, 0.9455)]
CRI6	[(0.4932, 0.6000), (0.5605, 0.6618)]	[(0.6214, 0.7230), (0.4177, 0.5159)]	[(0.6604, 0.7612), (0.3728, 0.4720)]	[(0.5651, 0.6650), (0.7090, 0.7867)]
CRI7	[(0.5550, 0.6520), (0.5336, 0.6331)]	[(0.8000, 0.9000), (0.3000, 0.4000)]	[(0.9500, 0.9900), (0.2000, 0.3000)]	[(0.6193, 0.7090), (0.4442, 0.5400)]
CRI8	[(0.4160, 0.5241), (0.6309, 0.7329)]	[(0.3634, 0.4762), (0.7620, 0.8423)]	[(0.4563, 0.5627), (0.7260, 0.8055)]	[(0.5313, 0.6316), (0.4720, 0.5716)]
CRI9	[(0.6581, 0.7464), (0.4059, 0.5014)]	[(0.4849, 0.5924), (0.7170, 0.7962)]	[(0.3175, 0.4327), (0.8364, 0.9016)]	[(0.4405, 0.5411), (0.6268, 0.7280)]
CRI10	[(0.2289, 0.3302), (0.8599, 0.9225)]	[(0.2080, 0.3175), (0.8583, 0.9314)]	[(0.2924, 0.4160), (0.8217, 0.9032)]	[(0.3915, 0.5013), (0.7334, 0.8139)]

Table 7. The weighted normalized decision matrix.

	UAV1	UAV2	UAV3	UAV4
CRI1	[(0.4783, 0.6178), (0.4699, 0.5850)]	[(0.6521, 0.7938), (0.3763, 0.4945)]	[(0.5383, 0.6713), (0.4263, 0.5424)]	[(0.4783, 0.6178), (0.4699, 0.5850)]
CRI2	[(0.5246, 0.6587), (0.4740, 0.5859)]	[(0.4104, 0.5504), (0.4945, 0.6109)]	[(0.3374, 0.4717), (0.6093, 0.7201)]	[(0.2947, 0.4286), (0.7512, 0.8360)]
CRI3	[(0.6905, 0.8194), (0.3613, 0.4784)]	[(0.7600, 0.8910), (0.3264, 0.4469)]	[(0.4272, 0.5571), (0.5647, 0.6755)]	[(0.6905, 0.8194), (0.3613, 0.4784)]
CRI4	[(0.1174, 0.2005), (0.8445, 0.9186)]	[(0.0909, 0.1731), (0.9128, 0.9655)]	[(0.0711, 0.1374), (0.9299, 0.9721)]	[(0.1216, 0.2086), (0.8769, 0.9380)]
CRI5	[(0.0200, 0.0600), (0.9895, 0.9986)]	[(0.0159, 0.0524), (0.9921, 0.9992)]	[(0.0531, 0.1200), (0.9576, 0.9887)]	[(0.0288, 0.0796), (0.9840, 0.9974)]
CRI6	[(0.2080, 0.3145), (0.7012, 0.8065)]	[(0.2621, 0.3790), (0.6404, 0.7504)]	[(0.2785, 0.3990), (0.6265, 0.7374)]	[(0.2383, 0.3485), (0.7873, 0.8692)]
CRI7	[(0.4272, 0.5571), (0.5647, 0.6755)]	[(0.6158, 0.7690), (0.3901, 0.5095)]	[(0.7312, 0.8459), (0.3449, 0.4609)]	[(0.4767, 0.6058), (0.4905, 0.6027)]

Table 7. Continued.

	UAV1	UAV2	UAV3	UAV4
CRI8	[(0.1293, 0.2181), (0.8420, 0.9166)]	[(0.1129, 0.1981), (0.8879, 0.9463)]	[(0.1418, 0.2341), (0.8741, 0.9356)]	[(0.1651, 0.2628), (0.8034, 0.8843)]
CRI9	[(0.4090, 0.5397), (0.5129, 0.6266)]	[(0.3013, 0.4283), (0.7457, 0.8305)]	[(0.1973, 0.3128), (0.8505, 0.9164)]	[(0.2738, 0.3912), (0.6703, 0.7776)]
CRI10	[(0.0600, 0.1200), (0.9367, 0.9762)]	[(0.0545, 0.1154), (0.9360 0.9788)]	[(0.0766, 0.1512), (0.9214, 0.9707)]	[(0.1026, 0.1822), (0.8895, 0.9476)]

Table 8. The matrix of theoretical ponder.

CRI1	[(0.5207, 0.6007), (0.7531, 0.8039)]	[(0.5207, 0.6007), (0.7531, 0.8039)]	[(0.5207, 0.6007), (0.7531, 0.8039)]	[(0.5207, 0.6007), (0.7531, 0.8039)]
CRI2	[(0.4513, 0.5352), (0.7919, 0.8367)]	[(0.4513, 0.5352), (0.7919, 0.8367)]	[(0.4513, 0.5352), (0.7919, 0.8367)]	[(0.4513, 0.5352), (0.7919, 0.8367)]
CRI3	[(0.6494, 0.7453), (0.7022, 0.7639)]	[(0.6494, 0.7453), (0.7022, 0.7639)]	[(0.6494, 0.7453), (0.7022, 0.7639)]	[(0.6494, 0.7453), (0.7022, 0.7639)]
CRI4	[(0.1965, 0.2645), (0.9377, 0.9610)]	[(0.1965, 0.2645), (0.9377, 0.9610)]	[(0.1965, 0.2645), (0.9377, 0.9610)]	[(0.1965, 0.2645), (0.9377, 0.9610)]
CRI5	[(0.0794, 0.1444), (0.9862, 0.9957)]	[(0.0794, 0.1444), (0.9862, 0.9957)]	[(0.0794, 0.1444), (0.9862, 0.9957)]	[(0.0794, 0.1444), (0.9862, 0.9957)]
CRI6	[(0.2682, 0.3366), (0.8762, 0.9119)]	[(0.2682, 0.3366), (0.8762, 0.9119)]	[(0.2682, 0.3366), (0.8762, 0.9119)]	[(0.2682, 0.3366), (0.8762, 0.9119)]
CRI7	[(0.5207, 0.6007), (0.7531, 0.8039)]	[(0.5207, 0.6007), (0.7531, 0.8039)]	[(0.5207, 0.6007), (0.7531, 0.8039)]	[(0.5207, 0.6007), (0.7531, 0.8039)]
CRI8	[(0.1965, 0.2645), (0.9377, 0.9610)]	[(0.1965, 0.2645), (0.9377, 0.9610)]	[(0.1965, 0.2645), (0.9377, 0.9610)]	[(0.1965, 0.2645), (0.9377, 0.9610)]
CRI9	[(0.4048, 0.4819), (0.8039, 0.8475)]	[(0.4048, 0.4819), (0.8039, 0.8475)]	[(0.4048, 0.4819), (0.8039, 0.8475)]	[(0.4048, 0.4819), (0.8039, 0.8475)]
CRI10	[(0.1655, 0.2303), (0.9456, 0.9679)]	[(0.1655, 0.2303), (0.9456, 0.9679)]	[(0.1655, 0.2303), (0.9456, 0.9679)]	[(0.1655, 0.2303), (0.9456, 0.9679)]

Table 9. The matrix of real ponder.

	UAV1	UAV2	UAV3	UAV4
CRI1	[(0.0000, 0.0000), (0.1000, 0.1000)]	[(0.5207, 0.6007), (0.7531, 0.8039)]	[(0.3727, 0.4341), (0.9057, 0.9266)]	[(0.0000, 0.0000), (0.1000, 0.1000)]
CRI2	[(0.4513, 0.5352), (0.7919, 0.8367)]	[(0.4110, 0.4888), (0.8402, 0.8754)]	[(0.3322, 0.3967), (0.9136, 0.9333)]	[(0.0000, 0.0000), (0.1000, 0.1000)]
CRI3	[(0.6079, 0.7021), (0.7550, 0.8073)]	[(0.6494, 0.7453), (0.7022, 0.7639)]	[(0.0000, 0.0000), (0.1000, 0.1000)]	[(0.6079, 0.7021), (0.7550, 0.8073)]
CRI4	[(0.1965, 0.2645), (0.9377, 0.9610)]	[(0.1163, 0.1568), (0.9868, 0.9918)]	[(0.0000, 0.0000), (0.1000, 0.1000)]	[(0.1738, 0.2340), (0.9565, 0.9729)]
CRI5	[(0.0330, 0.0601), (0.9990, 0.9997)]	[(0.0000, 0.0000), (0.1000, 0.1000)]	[(0.0794, 0.1444), (0.9862, 0.9957)]	[(0.0487, 0.0887), (0.9968, 0.9990)]
CRI6	[(0.2189, 0.2751), (0.9309, 0.9513)]	[(0.2568, 0.3224), (0.8906, 0.9223)]	[(0.2682, 0.3366), (0.8762, 0.9119)]	[(0.0000, 0.0000), (0.1000, 0.1000)]
CRI7	[(0.0000, 0.0000), (0.1000, 0.1000)]	[(0.4658, 0.5398), (0.8199, 0.8583)]	[(0.5207, 0.6007), (0.7531, 0.8039)]	[(0.3239, 0.3779), (0.9376, 0.9517)]
CRI8	[(0.1549, 0.2087), (0.9690, 0.9808)]	[(0.0000, 0.0000), (0.1000, 0.1000)]	[(0.1195, 0.1611), (0.9857, 0.9963)]	[(0.1965, 0.2645), (0.9377, 0.9610)]
CRI9	[(0.4048, 0.4819), (0.8039, 0.8475)]	[(0.2927, 0.3503), (0.9224, 0.9406)]	[(0.0000, 0.0000), (0.1000, 0.1000)]	[(0.3206, 0.3834), (0.8989, 0.9223)]
CRI10	[(0.1637, 0.2279), (0.9473, 0.9689)]	[(0.1655, 0.2303), (0.9456, 0.9679)]	[(0.1455, 0.2026), (0.9627, 0.9781)]	[(0.0000, 0.0000), (0.1000, 0.1000)]

Table 10. The matrix of total gap and ranking.

	CRI1	CRI2	CRI3	CRI4	CRI5	CRI6	CRI7	CRI8	CRI9	CRI10	Total(B_i)	Ranking
UAV1	0,3546	0,0000	0,0650	0,0000	0,0139	0,0585	0,3546	0,0348	0,0000	0,0017	0,8832	2
UAV2	0,0000	0,0568	0,0000	0,0563	0,0158	0,0150	0,0798	0,0764	0,1397	0,0000	0,4397	1
UAV3	0,1925	0,1502	0,4751	0,0764	0,0000	0,0000	0,0000	0,0549	0,2579	0,0177	1,2248	3
UAV4	0,3546	0,2907	0,0650	0,0206	0,0111	0,1465	0,2389	0,0000	0,1101	0,0624	1,2999	4

Table 11. Sensitivity analysis.

	Original	K3-K7	K2-K3	K3-K9	K1-K4	K7-K9	K1-K9
A1	2	2	2	2	1	2	2
A2	1	1	1	1	2	1	1
A3	3	3	3	3	4	4	4
A4	4	4	4	4	3	3	3

Table 12. Comparison analysis.

	The proposed Method	MAIRCA	TOPSIS	VIKOR
A1	2	2	2	2
A2	1	1	1	1
A3	3	3	4	4
A4	4	4	3	3

5 Conclusions

UAV usage areas are becoming more widespread day by day. Parallel to this increase in UAV systems, both the use of these systems and their production with domestic resources have increased in our country. UAVs have an advantage over other warfare vehicles, thanks to the fact that they can be equipped with different equipment according to the situations in which they are intended to be used. In addition, thanks to this flexibility, its ability to adapt to instant changes in operational activities is one of its biggest advantages, and thanks to these advantages and more, it has become the biggest advantage for the personnel at command and control levels. It is an undeniable fact that UAVs used in the military field have become a very useful technology, especially since they minimize the risk of life-threatening for personnel. It can be used effectively, especially for reconnaissance and surveillance, intelligence activities and target destruction in areas where operations are difficult to carry out, by taking advantage of long hours in the air to carry out tasks that many personnel working within the Turkish Armed Forces spend a long time on. It is thought that UAVs will be needed in the future and their active use will continue for a long time. States produce or purchase such war equipment for defense purposes against possible attacks on their countries, add them to their inventories, and seek answers to their needs. At this point, the selection phase plays an extremely critical role in order to use resources effectively in meeting the needs through purchasing.

Considering the widespread use and contributions of UAV systems, decision-making by decision makers becomes critical. When studies in the literature are examined, MCDM methods have been widely used in weighting and selection of criteria, but it is difficult to express the sensitivity of the relationship between alternatives and criteria. In order to eliminate the complexities that arise during the weighting of the criteria, it is aimed to eliminate this complexity by using an interval-valued q-rung orthopair fuzzy set. Within the scope of the paper, it is envisaged to make a selection with the help of solution matrices created among four different UAV alternatives that are mass produced and used worldwide, using the importance weightings made according to the opinions received from the command level and the Mairca method based on interval-valued q-rung orthopair fuzzy set as a result of these weights. In the solution phase, firstly, the criterion importance levels received as linguistic expressions from 3 different experts were tabulated, and then the expert opinions were arranged as the weighting of the criteria and alternatives. As a result of blurring the resulting table, a new solution matrix was obtained and as a result of the operations to be carried out by following the steps of the q-rung orthopair fuzzy set-based Mairca method, it was determined that the best choice was the A2 alternative. If suitable conditions were not met for the selection of the A2 alternative, the other options were ranked according to their values and the order A2 < A3 < A1 < A4 was created. Alternative A2, which is the smallest of the calculated values and the best result, was determined as the best alternative. Then, the second best alternative is A3, the third best alternative is A1, and the last alternative is A4. In addition, it is possible to make calculations with more criteria and alternatives in changing strategies and conditions with the solution method created by the MAIRCA method based on interval-valued q-rung orthopair fuzzy numbers. The method is established in a flexible framework, and if the number of alternatives and constraints changes, it can be stretched and made suitable for the new problem to be created.

The limitation of this paper is to define the weights of the criteria by using an aggregation operator. It aims to use a pairwise comparison matrix among criteria in future studies. Although this study handles ten criteria for UAV selection problem, different criteria can be added and reduced in future studies. Ten criteria are seen enough according to opinions of three experts of this paper. The proposed method can also used for different number of criteria. It can be employed for different defense related selection problems such as aircraft selection, weapon selection. In this case, it will be sufficient adding suitable criteria for the related selection problems. This proposed new MCDM (IVqROF number based MAIRCA) method can be used in all complex decision-making problems involving conflicting and uncertain criteria except UAVs selection problem. There are many MCDM methods in the literature and new methods continue to be added. In future studies, research can be conducted using interval-valued q-ROF number integration of different decision-making methods. Interval valued q-ROF numbers can be developed with new extensions and used as a basis for other MCDM methods in the literature.

6 Author contribution statement

Burak YELBEY contributed to formation of the idea, literature review, data collection, supplying the materials, conducting the analyses, design, writing and assessment of the obtained results. Burak EFE and Leyla EFE contributed to formation of the idea, design, writing and assessment of the obtained results.

7 Ethics committee approval and conflict of interest statement

“There is no need to obtain permission from the ethics committee for the article prepared”.

“There is no conflict of interest with any person / institution in this article prepared”.

8 Kaynaklar

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