

Using the PARIS Method for Multiple Criteria Decision Making in Unmanned Combat Aircraft Evaluation and Selection

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Abstract—Unmanned combat aircraft (UCA) are expanding significantly in several defense industries, along with artificial intelligence improvements in highly precise technology. UCA is crucial in military settings for targeting enemy elements, and objects. UCA is also utilized for highly precise reconnaissance and surveillance tasks. To select the best alternative for critical missions, a methodical and effective strategy for UCA selection is required. Multiple criteria decision-making (MCDM) methodologies are ideally equipped to handle the complexity of alternative aircraft selection. To analyze UCA alternatives for the selection process, an integrated methodology built on the objective criteria weights and preference analysis for reference ideal solution (PARIS). First, the weights of essential elements are determined using the average weight (AW), standard deviation (SW) and entropy weight (EW) approach. The weights of the evaluation criteria affect the decision-making process. The aircraft choices in the decision problem are then ranked using objective criteria weights along with the PARIS technique. The validation and sensitivity analysis of the proposed MCDM approach are discussed.

Keywords—Unmanned combat aircraft (UCA), multiple criteria decision making, MCDM, PARIS.

I. INTRODUCTION

As the global military risks reach an ultracritical level, defense authorities regularly make complicated judgments while taking into account a wide range of evaluation variables. When purchasing unmanned combat aircraft, decisions concerning defense sustainability usually mix a number of objective evaluation factors with highly subjective value judgments.

This evaluation process is usually accomplished utilizing the decision maker's intuition, which, regrettably, can result in inconsistent decision-making and doubt regarding whether the proper preferences are reflected in the decision policy. Multiple criteria decision analysis, a systematic procedure can be a useful apparatus for decision-makers to assess competing options in a multifaceted defense context.

In military decision-making settings, decision trees, a visual decision support tool that visualizes choices and their likely results, are frequently used as part of a systematic approach to decision making. Unfortunately, the capacity of simple decision trees to handle complicated issues with several conflicting decision criteria is relatively constrained.

The choice could get more difficult if additional factors need to be considered. Then, modeling all available attributes simultaneously in a single decision-making model becomes

necessary. To do this, each characteristic would need to be transformed into a single common measure, after which each attribute would need to be traded off in order to arrive at a weighting that accurately reflects the decision maker's relative preferences.

Multiple criteria decision making (MCDM) analysis is the name of the overall method for methodically tackling various kinds of situations. The MCDM method has four stages in its most basic form [1-3]:

Framing the decision and identifying the goals and objectives that the decision maker must achieve,

Identification of all decision options (alternatives) and any relevant characteristics (attributes) that pertain to the decision-making goals,

Specifying preferences for all the attributes individually as well as between the elements in the framework,

Ranking the choice alternatives based on the given preferences, with knowledge of each decision alternative's attribute data.

It's significant to remember that such preferences exist for each characteristic as well as between attributes. Preferences serve as the foundation for making logical decisions once they are established.

In a multiple attribute decision-making situation, the various attributes are probably measured in several units. Some characteristics, like "maneuverability," of the aircraft might even be quantified.

In order to formalize a common unit's assessment and to identify the decision maker's preferences for each attribute across its respective unit's scale, the MCDM framework uses multiple attribute utility theory (MAUT) [4]. The steps in the application process for MAUT are:

Defining the characteristics (attributes) to be used to evaluate the decision goals,

Normalizing all attributes' measurements or scales uniformly across all possible options,

Weighing the preferences for those characteristics (attributes).

For each attribute, the decision-maker must develop a single measure utility function in step two. With the help of mathematics, this utility function converts monetary or other values into utility values. As a result, there is a utility value

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$U_{(x)}$ on a standard scale, such as 0 to 1, for each value of an attribute x .

Utility is determined for qualitative features once an assessment scale is created and the utility function is built using that scale. Consistency checks should be done carefully.

Once the preferences for individual attributes are specified, the decision maker can then establish preferences between the characteristics by stating the weights in a multiple attribute utility function of the following form:

$$U_{(x)} = \sum_{j=1}^J u_i(x_i)\omega_j, 1 \leq i \leq I, 1 \leq j \leq J \quad (1)$$

where utility function $U_{(x)}$; normalized utility values $u_i(x_i)$, weight values ω_j are given.

Decision models under MAUT abide by a set of fundamental principles for "clear thinking" that specify their structure and assist the decision maker in avoiding inconsistency. Examples of decision model attributes based on MAUT include decision alternatives can be ranked ordered, at which point the ordering is transitive, and independence states that a third, unrelated option cannot change the orderings between two alternatives. These MAUT axioms aid decision makers in avoiding certain paradoxes in their decision-making processes. This procedure aims to produce a model that can withstand scrutiny and produce consistent results.

Unmanned combat aircraft are evaluated based on a variety of factors, including economic, environmental, and technological factors. Multiple criterion decision making approach is widely used to solve such complex problems. One of the key components of decision theory, it offers a versatile concept that can handle and combine a variety of factors assessed in various ways and so provide the decision makers with useful support.

For the examination and selection of alternatives under a set of criteria, numerous multiple criteria-based decision making systems have been created. A matrix made up of rows of alternatives and columns of target criteria was used to depict the multidimensional assessment of alternatives. Using an MAUT methodology, the options are examined, and the outcomes are contrasted using sensitivity analysis.

Using Shannon's entropy weight (EW) approach, the relative weights for the various properties were determined. Other objective criteria weight methods are average weight (AW), and standard deviation weight (SW). Many MCDM evaluation and selection problems use the AHP (Analytic Hierarchy Process) [5-8], TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) [9-10], and VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) [11-12] approach that is a multiple criteria decision making analysis method.

For the evaluation of alternatives, PROMETHEE (Preference Ranking Organisation Method for Enrichment of Evaluations) [13-16], which is based on the outranking method, is used. To assess the options, ELECTRE (ELimination Et Cholx Traduisant la REalite) [17-18], another outranking methodology, is presented. To choosing

the best alternative, a modified fuzzy methodology integrating fuzzy AHP and TOPSIS is put forth. Fuzzy AHP was used to calculate the selection criteria weights, while TOPSIS was used to assess the alternatives. Also, standard fuzzy sets (SFS) and their extensions have been applied to numerous MCDM problems [20-31].

Following a thorough examination of the aforementioned MCDM techniques and their applications for the assessment and choice of unmanned combat aircraft, it is found that the multiple criteria decision making methods have a tendency to be sophisticated, knowledge-intensive, involve more computations, and are less effective when dealing with circumstances where there are alternatives for consideration [32-55].

There is no a single MCDM approach that works as effectively for all decision problems. A straightforward, organized, logical, and consistent approach or instrument is required to assist decision-makers in selecting the best choice. As a result, MCDM methodology for the assessment and selection of unmanned combat aircraft is established by integrating objective criteria weights.

The rest of the paper is organized as follows: In Section 2, the PARIS (Preference Analysis for Reference Ideal Solution) method, and the objective criteria weights methods are presented. In Section 3, application of the proposed methodology is presented for selecting unmanned combat aircraft. In Section 4, concluding remarks and future research directions are discussed.

II. METHODOLOGY

A. The PARIS (Preference Analysis for Reference Ideal Solution) Method

Suppose that multiple criteria decision making (MCDM) analysis problem has I alternatives $a_i = (a_{i1}, \dots, a_{ij}, \dots, a_{iJ})$, $i \in \{i = 1, \dots, I\}$, and J criteria $g_j = (g_{j1}, \dots, g_{ij}, \dots, g_{jJ})$, $j \in \{j = 1, \dots, J\}$, and the importance weight of each criterion (ω_j , $j \in \{j = 1, \dots, J\}$) is defined.

The PARIS method is performed according to the following procedural steps [56-61]:

Step 1. Constructing the decision matrix $X = [x_{ij}]_{i \times j}$

$$X = \begin{pmatrix} g_1 & \cdots & g_j \\ x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{pmatrix}_{i \times j} \quad (2)$$

Step 2. Normalizing the decision matrix

a. Normalizing way 1 (Vector normalization):

If g_j is the criterion, the bigger the better

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^I x_{ij}^2}} \quad (3) \quad z_j^* = \{z_1^*, \dots, z_j^*\} = \{(max_i z_{ij} \mid j \in B), (\min_i z_{ij} \mid j \in C)\} \quad (11)$$

If g_j is the criterion, the smaller the better

$$r_{ij} = 1 - \frac{x_{ij}}{\sqrt{\sum_{i=1}^I x_{ij}^2}} \quad (4)$$

b. Normalizing way 2 (Linear normalization):

If g_j is the criterion, the bigger the better

$$r_{ij} = \frac{x_{ij}}{x_j^{\max}} \quad (5)$$

If g_j is the criterion, the smaller the better

$$r_{ij} = \frac{x_j^{\min}}{x_{ij}} \quad (6)$$

c. Normalizing way 3 (Max-Min linear normalization):

If g_j is the criterion, the bigger the better

$$r_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (7)$$

If g_j is the criterion, the smaller the better

$$r_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \quad (8)$$

Step 3. Calculating the weighted normalized value

$$z_{ij} = \omega_j r_{ij} \quad (9)$$

Step 4. Summarizing the weighted normalized values

$$\pi_i = \sum_{j=1}^J \omega_j r_{ij} \quad (10)$$

Step 5. Rank the alternatives. The solution with the largest value of π_i is the best solution.

Step 6. Identifying the elements of reference ideal solution (z_j^*)

where B represents a criterion as large as possible, C represents a criterion as small as possible.

Step 7. Calculating the distance $d_{ij} = (z_j^* - z_{ij})$ from the reference ideal solution (z_j^*)

$$\pi_i^* = \sum_{j=1}^J (z_j^* - z_{ij}) = \sum_{j=1}^J d_{ij} \quad (12)$$

Step 8. Rank the alternatives according to the principle that the one with the smallest value of π_i^* is the best choice.

Step 9. Calculating the distance from the alternatives to the ideal solution.

$$R_i = \left[(\pi_i - \pi_i^{\max})^2 + (\pi_i^* - \pi_i^{*,\min})^2 \right]^{1/2} \quad (13)$$

Step 10. Rank the alternatives according to the principle that the one with the smallest value of R_i is the best choice.

B. Methods of Determining Weights

a. The Average Weight Method

Average weight (AW) is determined according to the following formula.

$$\omega_j = \frac{1}{J}, \quad j = 1, \dots, J \quad (14)$$

$$\sum_{j=1}^J \omega_j = 1, \quad \omega_j > 0, \quad j = 1, \dots, J$$

where $j = 1, \dots, J$ is the number of criteria, and ω_j is the weight of the j th criterion g_j .

b. The Standard Deviation Weight Method

Standard deviation weight (SW) is determined according to the following steps:

Step 1. Determining the factors' normalized values $X = [x_{ij}]_{i \times j}$

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^I x_{ij}} \quad (15)$$

Step 2. Determining the standard deviation value for each factor

$$\sigma_j = \sqrt{\frac{1}{I} \sum_{i=1}^I (p_{ij} - \mu_j)^2} \quad (16)$$

$$\mu_j = \frac{1}{I} \sum_{i=1}^I r_{ij}$$

Step 3. Determining the standard deviation weight for each factor

$$\omega_j = \frac{\sigma_j}{\sum_{j=1}^J \sigma_j} \quad (17)$$

$$\sum_{j=1}^J \omega_j = 1, \omega_j > 0, i = 1, \dots, I, j = 1, \dots, J$$

where σ_j is the standard deviation, μ_j is the mean value of the j th normalized factor p_{ij} , and ω_j is the weight of the j th criterion g_j .

c. The Entropy Weight Method

The entropy weight (EW) is determined according to the following steps.

Step 1. Determining the factors' normalized values $X = [x_{ij}]_{i \times j}$

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^I x_{ij}} \quad (18)$$

where x_{ij} is the value of criterion j corresponding to option i and I is the number of alternatives.

Step 2. Determining the Entropy measure's value for each factor

$$E_j = -\frac{1}{\ln I} \sum_{i=1}^I p_{ij} \ln p_{ij} \quad (19)$$

Step 3. Determining the entropy weight for each factor

$$\omega_j = \frac{1 - E_j}{\sum_{j=1}^J (1 - E_j)} \quad (20)$$

$$\sum_{j=1}^J \omega_j = 1, \omega_j > 0, i = 1, \dots, I, j = 1, \dots, J$$

where ω_j is the weight of the j th criterion g_j .

III. APPLICATION

A. UCA (Unmanned combat Aircraft) Selection Index

Unmanned combat aircraft (UCA) selection index (R_i) is a metric of comparative value that can be used to choose an unmanned combat aircraft for a certain defense application. The selection index is used to evaluate the UCA selection function that incorporates measures of attributes and their relative importance. The selection index R_i is the UCA selection function's numerical value. Lower values of R_i will produce the desired value of the UCA selection index because the UCA selection function comprises the quantitative measures of UCA selection attributes. The values of attributes x_{ij} are necessary information to calculate this index.

B. The Values of Attributes

It is preferable to determine the value of R_i from actual or estimated data. When quantitative values for the attributes are available, normalized values for the attributes assigned to the alternatives are calculated using the Equations (2) – (8). Normalized values assigned to alternatives for a given application are either based on a beneficial attribute indicating higher measures are more desirable or based on a non-beneficial attribute indicating lower measures are more desirable. A ranked value assessment on a fuzzy conversion scale is used when a quantitative value is unavailable. The value of the attributes (x_{ij}) can be first determined as linguistic terms, converted into corresponding fuzzy numbers, and then converted to crisp scores using fuzzy set theory, $S = \{ \langle x, \mu_S(x) \rangle \mid \forall x \in X \}$, the membership degree of an element is μ , its non-membership is $\nu = 1 - \mu$, and its indeterminacy degree is accepted as "0", $\pi = 1 - \mu - \nu$ [19]. A numerical approximation approach was proposed to systematically convert linguistic concepts into their corresponding fuzzy numbers [62]. Table 1 is suggested which corresponds to the fuzzy conversion scale (11-point scale) in Fig. 1 and displays the UCA selection feature on a qualitative scale using fuzzy logic.

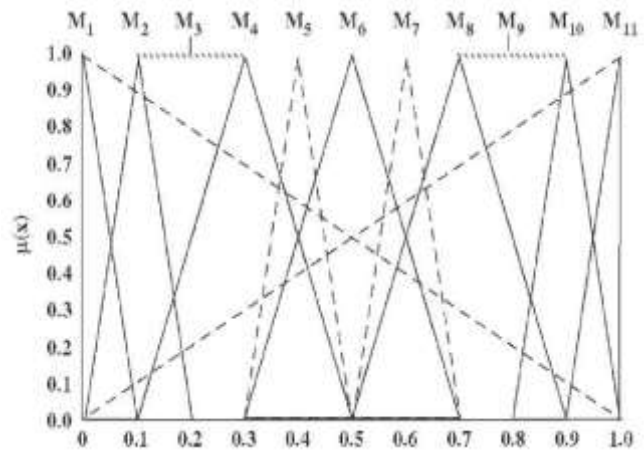


Fig. 1 Linguistic term into their corresponding fuzzy numbers (11-point scale)

The normalized values of the attribute assigned for various alternatives are then determined in the same way as for quantitative attributes once a qualitative attribute is represented on a conversion scale. An 11-point scale is only taken into consideration in this work for a precise description of the value of a qualitative attribute.

Table 1. Values of UCA selection attributes and conversion of linguistic terms into fuzzy scores (11-point scale)

Qualitative measures of UCAV selection attributes	Fuzzy number	Assigned values
Exceptionally low	M_1	0,045
Extremely low	M_2	0,135
Very low	M_3	0,255
Low	M_4	0,335
Below average	M_5	0,410
Average	M_6	0,500
Above average	M_7	0,590
High	M_8	0,665
Very high	M_9	0,745
Extremely high	M_{10}	0,865
Exceptionally high	M_{11}	0,955

C. Determining the Weights of the Criteria

In the multiple criteria decision analysis, considering a selection problem with unmanned combat aircraft acquisition, six choice criteria are chosen by the Air Force experts' group to evaluate UCA alternatives. The six decision criteria were used to evaluate the UCA systems: costability g_1 , payloadability g_2 , maneuverability g_3 , speedability g_4 , stealthility g_5 , and survivability g_6 . Only one of these six attributes, costability g_1 is non-beneficial. The other five attributes, payloadability g_2 , maneuverability g_3 , speedability g_4 , stealthability g_5 , and survivability g_6 , are considered beneficial [32-59].

Equation (2) is used to construct the decision matrix as shown in Table 2. Equation (14) was applied to determine the weights of the criteria according to the AW method. In addition, Equations (15)-(17) are used to determine the weights for the criteria according to the SW method. Equations (18)-(20) determine the weights of the criteria of the EW method. The computed results are shown in Table 3.

Table 2. Decision matrix

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,745	0,335	0,955	0,665	0,600	0,410
A2	0,865	0,500	0,865	0,865	0,335	0,665
A3	0,745	0,955	0,665	0,745	0,745	0,955
A4	0,590	0,045	0,410	0,335	0,410	0,255
A5	0,665	0,500	0,865	0,865	0,135	0,745
A6	0,590	0,745	0,590	0,865	0,335	0,500
A7	0,255	0,745	0,135	0,335	0,255	0,665
A8	0,865	0,335	0,745	0,045	0,665	0,410
A9	0,590	0,745	0,665	0,335	0,410	0,590
A10	0,500	0,665	0,590	0,665	0,045	0,745
A11	0,335	0,255	0,865	0,135	0,665	0,500
A12	0,045	0,955	0,255	0,590	0,255	0,865
A13	0,500	0,590	0,335	0,045	0,590	0,410
A14	0,410	0,500	0,955	0,665	0,500	0,500

A15	0,255	0,410	0,865	0,865	0,135	0,045
A16	0,135	0,955	0,590	0,745	0,665	0,335
A17	0,745	0,865	0,665	0,045	0,135	0,335
A18	0,500	0,335	0,665	0,500	0,665	0,500
A19	0,665	0,410	0,335	0,865	0,745	0,590
A20	0,410	0,255	0,410	0,045	0,410	0,255

Table 3. Objective criteria weights

Method	g_1	g_2	g_3	g_4	g_5	g_6
AW	0,167	0,167	0,167	0,167	0,167	0,167
SW	0,154	0,166	0,135	0,216	0,180	0,150
EW	0,141	0,151	0,102	0,296	0,185	0,125

D. Applying the PARIS Method

Equations (3) and (4) are used to normalize the matrix in way 1. Equations (5) and (6) are applied to normalize the matrix in way 2. Equations (7) and (8) are used to normalize the matrix in way 3. The results are presented in Tables 4 - 6.

Table 4. Normalized decision matrix using Way 1

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,706	0,122	0,321	0,249	0,275	0,165
A2	0,659	0,183	0,291	0,324	0,154	0,267
A3	0,706	0,349	0,224	0,279	0,342	0,383
A4	0,767	0,016	0,138	0,125	0,188	0,102
A5	0,738	0,183	0,291	0,324	0,062	0,299
A6	0,767	0,272	0,199	0,324	0,154	0,201
A7	0,900	0,272	0,045	0,125	0,117	0,267
A8	0,659	0,122	0,251	0,017	0,305	0,165
A9	0,767	0,272	0,224	0,125	0,188	0,237
A10	0,803	0,243	0,199	0,249	0,021	0,299
A11	0,868	0,093	0,291	0,051	0,305	0,201
A12	0,982	0,349	0,086	0,221	0,117	0,347
A13	0,803	0,216	0,113	0,017	0,271	0,165
A14	0,838	0,183	0,321	0,249	0,229	0,201
A15	0,900	0,150	0,291	0,324	0,062	0,018
A16	0,947	0,349	0,199	0,279	0,305	0,134
A17	0,706	0,316	0,224	0,017	0,062	0,134
A18	0,803	0,122	0,224	0,187	0,305	0,201
A19	0,738	0,150	0,113	0,324	0,342	0,237
A20	0,838	0,093	0,138	0,017	0,188	0,102

Table 5. Normalized decision matrix using Way 2

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,060	0,351	1,000	0,769	0,805	0,429
A2	0,052	0,524	0,906	1,000	0,450	0,696
A3	0,060	1,000	0,696	0,861	1,000	1,000
A4	0,076	0,047	0,429	0,387	0,550	0,267
A5	0,068	0,524	0,906	1,000	0,181	0,780
A6	0,076	0,780	0,618	1,000	0,450	0,524
A7	0,176	0,780	0,141	0,387	0,342	0,696
A8	0,052	0,351	0,780	0,052	0,893	0,429
A9	0,076	0,780	0,696	0,387	0,550	0,618
A10	0,090	0,696	0,618	0,769	0,060	0,780
A11	0,134	0,267	0,906	0,156	0,893	0,524
A12	1,000	1,000	0,267	0,682	0,342	0,906
A13	0,090	0,618	0,351	0,052	0,792	0,429
A14	0,110	0,524	1,000	0,769	0,671	0,524
A15	0,176	0,429	0,906	1,000	0,181	0,047
A16	0,333	1,000	0,618	0,861	0,893	0,351
A17	0,060	0,906	0,696	0,052	0,181	0,351
A18	0,090	0,351	0,696	0,578	0,893	0,524
A19	0,068	0,429	0,351	1,000	1,000	0,618
A20	0,110	0,267	0,429	0,052	0,550	0,267

Table 6. Normalized decision matrix using Way 3

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,146	0,319	1,000	0,756	0,793	0,401
A2	0,000	0,500	0,890	1,000	0,414	0,681
A3	0,146	1,000	0,646	0,854	1,000	1,000
A4	0,335	0,000	0,335	0,354	0,521	0,231
A5	0,244	0,500	0,890	1,000	0,129	0,769
A6	0,335	0,769	0,555	1,000	0,414	0,500
A7	0,744	0,769	0,000	0,354	0,300	0,681
A8	0,000	0,319	0,744	0,000	0,886	0,401
A9	0,335	0,769	0,646	0,354	0,521	0,599
A10	0,445	0,681	0,555	0,756	0,000	0,769
A11	0,646	0,231	0,890	0,110	0,886	0,500
A12	1,000	1,000	0,146	0,665	0,300	0,901
A13	0,445	0,599	0,244	0,000	0,779	0,401
A14	0,555	0,500	1,000	0,756	0,650	0,500
A15	0,744	0,401	0,890	1,000	0,129	0,000
A16	0,890	1,000	0,555	0,854	0,886	0,319
A17	0,146	0,901	0,646	0,000	0,129	0,319
A18	0,445	0,319	0,646	0,555	0,886	0,500
A19	0,244	0,401	0,244	1,000	1,000	0,599
A20	0,555	0,231	0,335	0,000	0,521	0,231

Equation (9) is used to calculate the weighted normalized value (z_{ij}). The results are presented in Tables 7 - 9. Equation (10) is used to summarize the weighted normalized values (π_i). The results are presented in Table 11. Equation (11) is used to identify the elements of reference ideal solution (z_j^*). The results are presented in Table 10.

Table 7. Values of z_{ij} utilizing the AW-Way 1 technique

UCAVs	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,118	0,020	0,054	0,041	0,046	0,027
A2	0,110	0,030	0,049	0,054	0,026	0,044
A3	0,118	0,058	0,037	0,046	0,057	0,064
A4	0,128	0,003	0,023	0,021	0,031	0,017
A5	0,123	0,030	0,049	0,054	0,010	0,050
A6	0,128	0,045	0,033	0,054	0,026	0,033
A7	0,150	0,045	0,008	0,021	0,019	0,044
A8	0,110	0,020	0,042	0,003	0,051	0,027
A9	0,128	0,045	0,037	0,021	0,031	0,039
A10	0,134	0,040	0,033	0,041	0,003	0,050
A11	0,145	0,016	0,049	0,008	0,051	0,033
A12	0,164	0,058	0,014	0,037	0,019	0,058
A13	0,134	0,036	0,019	0,003	0,045	0,027
A14	0,140	0,030	0,054	0,041	0,038	0,033
A15	0,150	0,025	0,049	0,054	0,010	0,003
A16	0,158	0,058	0,033	0,046	0,051	0,022
A17	0,118	0,053	0,037	0,003	0,010	0,022
A18	0,134	0,020	0,037	0,031	0,051	0,033
A19	0,123	0,025	0,019	0,054	0,057	0,039
A20	0,140	0,016	0,023	0,003	0,031	0,017

Table 8. Values of z_{ij} utilizing the AW-Way 2 technique

UCAVs	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,010	0,058	0,167	0,128	0,134	0,072
A2	0,009	0,087	0,151	0,167	0,075	0,116
A3	0,010	0,167	0,116	0,144	0,167	0,167
A4	0,013	0,008	0,072	0,065	0,092	0,045
A5	0,011	0,087	0,151	0,167	0,030	0,130
A6	0,013	0,130	0,103	0,167	0,075	0,087

A7	0,029	0,130	0,024	0,065	0,057	0,116
A8	0,009	0,058	0,130	0,009	0,149	0,072
A9	0,013	0,130	0,116	0,065	0,092	0,103
A10	0,015	0,116	0,103	0,128	0,010	0,130
A11	0,022	0,045	0,151	0,026	0,149	0,087
A12	0,167	0,167	0,045	0,114	0,057	0,151
A13	0,015	0,103	0,058	0,009	0,132	0,072
A14	0,018	0,087	0,167	0,128	0,112	0,087
A15	0,029	0,072	0,151	0,167	0,030	0,008
A16	0,056	0,167	0,103	0,144	0,149	0,058
A17	0,010	0,151	0,116	0,009	0,030	0,058
A18	0,015	0,058	0,116	0,096	0,149	0,087
A19	0,011	0,072	0,058	0,167	0,167	0,103
A20	0,018	0,045	0,072	0,009	0,092	0,045

Table 9. Values of z_{ij} utilizing the AW-Way 3 technique

UCAVs	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,024	0,053	0,167	0,126	0,132	0,067
A2	0,000	0,083	0,148	0,167	0,069	0,114
A3	0,024	0,167	0,108	0,142	0,167	0,167
A4	0,056	0,000	0,056	0,059	0,087	0,038
A5	0,041	0,083	0,148	0,167	0,021	0,128
A6	0,056	0,128	0,092	0,167	0,069	0,083
A7	0,124	0,128	0,000	0,059	0,050	0,114
A8	0,000	0,053	0,124	0,000	0,148	0,067
A9	0,056	0,128	0,108	0,059	0,087	0,100
A10	0,074	0,114	0,092	0,126	0,000	0,128
A11	0,108	0,038	0,148	0,018	0,148	0,083
A12	0,167	0,167	0,024	0,111	0,050	0,150
A13	0,074	0,100	0,041	0,000	0,130	0,067
A14	0,092	0,083	0,167	0,126	0,108	0,083
A15	0,124	0,067	0,148	0,167	0,021	0,000
A16	0,148	0,167	0,092	0,142	0,148	0,053
A17	0,024	0,150	0,108	0,000	0,021	0,053
A18	0,074	0,053	0,108	0,092	0,148	0,083
A19	0,041	0,067	0,041	0,167	0,167	0,100
A20	0,092	0,038	0,056	0,000	0,087	0,038

Table 10. Values of z_j^* using AW method

Normalization	g_1	g_2	g_3	g_4	g_5	g_6
Way 1	0,164	0,058	0,054	0,054	0,057	0,064
Way 2	0,167	0,167	0,167	0,167	0,167	0,167
Way 3	0,167	0,167	0,167	0,167	0,167	0,167

Table 11. Rankings of UCA by the values of π_i utilizing the AW method

UCA	Way 1		Way 2		Way 3	
	π_i	Rank	π_i	Rank	π_i	Rank
A1	0,306	10	0,569	9	0,569	9
A2	0,313	8	0,605	4	0,581	8
A3	0,380	1	0,770	1	0,774	1
A4	0,223	20	0,293	19	0,296	20
A5	0,316	7	0,576	7	0,589	6
A6	0,319	5	0,575	8	0,596	5
A7	0,288	15	0,421	16	0,475	15
A8	0,253	17	0,426	15	0,392	17
A9	0,302	11	0,518	11	0,537	12
A10	0,302	12	0,502	12	0,534	13
A11	0,301	13	0,480	13	0,544	11
A12	0,350	3	0,700	2	0,669	3
A13	0,264	16	0,389	17	0,411	16
A14	0,337	4	0,599	5	0,660	4
A15	0,291	14	0,457	14	0,527	14
A16	0,369	2	0,676	3	0,751	2

A17	0,243	18	0,374	18	0,357	18
A18	0,307	9	0,522	10	0,558	10
A19	0,317	6	0,578	6	0,581	7
A20	0,229	19	0,279	20	0,312	19

A correlation analysis is used to determine the relationship between rankings of ordinal variables or different rankings of the same variable. An increasing correlation coefficient indicates increasing agreement between rankings. The correlation analysis of the rankings of UCA by the values of π_i utilizing the AW method is presented in Table 12.

Table 12. Correlation analysis of the rankings of UCA by the values of π_i utilizing the AW method

	Way 1	Way 2	Way 3
Way 1	1		
Way 2	0,971	1	
Way 3	0,992	0,967	1

Equation (12) is used to calculate the distance (d_{ij}) from the reference ideal solution (z_j^*). The results are presented in Tables 13-15. The ranking results of UCA by the values of π_i^* utilizing the AW method are presented in Table 17.

Table 13. Distance values (d_{ij}) from the reference ideal solution (z_j^*) utilizing the AW-Way 1 technique

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,046	0,038	0,000	0,012	0,011	0,036
A2	0,054	0,028	0,005	0,000	0,031	0,019
A3	0,046	0,000	0,016	0,007	0,000	0,000
A4	0,036	0,055	0,031	0,033	0,026	0,047
A5	0,041	0,028	0,005	0,000	0,047	0,014
A6	0,036	0,013	0,020	0,000	0,031	0,030
A7	0,014	0,013	0,046	0,033	0,037	0,019
A8	0,054	0,038	0,012	0,051	0,006	0,036
A9	0,036	0,013	0,016	0,033	0,026	0,024
A10	0,030	0,018	0,020	0,012	0,054	0,014
A11	0,019	0,043	0,005	0,046	0,006	0,030
A12	0,000	0,000	0,039	0,017	0,037	0,006
A13	0,030	0,022	0,035	0,051	0,012	0,036
A14	0,024	0,028	0,000	0,012	0,019	0,030
A15	0,014	0,033	0,005	0,000	0,047	0,061
A16	0,006	0,000	0,020	0,007	0,006	0,041
A17	0,046	0,005	0,016	0,051	0,047	0,041
A18	0,030	0,038	0,016	0,023	0,006	0,030
A19	0,041	0,033	0,035	0,000	0,000	0,024
A20	0,024	0,043	0,031	0,051	0,026	0,047

Table 14. Distance values (d_{ij}) from the reference ideal solution (z_j^*) utilizing the AW-Way 2 technique

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,157	0,108	0,000	0,039	0,032	0,095
A2	0,158	0,079	0,016	0,000	0,092	0,051
A3	0,157	0,000	0,051	0,023	0,000	0,000
A4	0,154	0,159	0,095	0,102	0,075	0,122
A5	0,155	0,079	0,016	0,000	0,136	0,037
A6	0,154	0,037	0,064	0,000	0,092	0,079

A7	0,137	0,037	0,143	0,102	0,110	0,051
A8	0,158	0,108	0,037	0,158	0,018	0,095
A9	0,154	0,037	0,051	0,102	0,075	0,064
A10	0,152	0,051	0,064	0,039	0,157	0,037
A11	0,144	0,122	0,016	0,141	0,018	0,079
A12	0,000	0,000	0,122	0,053	0,110	0,016
A13	0,152	0,064	0,108	0,158	0,035	0,095
A14	0,148	0,079	0,000	0,039	0,055	0,079
A15	0,137	0,095	0,016	0,000	0,136	0,159
A16	0,111	0,000	0,064	0,023	0,018	0,108
A17	0,157	0,016	0,051	0,158	0,136	0,108
A18	0,152	0,108	0,051	0,070	0,018	0,079
A19	0,155	0,095	0,108	0,000	0,000	0,064
A20	0,148	0,122	0,095	0,158	0,075	0,122

Table 15. Distance values (d_{ij}) from the reference ideal solution (z_j^*) utilizing the AW-Way 3 technique

UCAVs	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,142	0,114	0,000	0,041	0,035	0,100
A2	0,167	0,083	0,018	0,000	0,098	0,053
A3	0,142	0,000	0,059	0,024	0,000	0,000
A4	0,111	0,167	0,111	0,108	0,080	0,128
A5	0,126	0,083	0,018	0,000	0,145	0,038
A6	0,111	0,038	0,074	0,000	0,098	0,083
A7	0,043	0,038	0,167	0,108	0,117	0,053
A8	0,167	0,114	0,043	0,167	0,019	0,100
A9	0,111	0,038	0,059	0,108	0,080	0,067
A10	0,092	0,053	0,074	0,041	0,167	0,038
A11	0,059	0,128	0,018	0,148	0,019	0,083
A12	0,000	0,000	0,142	0,056	0,117	0,016
A13	0,092	0,067	0,126	0,167	0,037	0,100
A14	0,074	0,083	0,000	0,041	0,058	0,083
A15	0,043	0,100	0,018	0,000	0,145	0,167
A16	0,018	0,000	0,074	0,024	0,019	0,114
A17	0,142	0,016	0,059	0,167	0,145	0,114
A18	0,092	0,114	0,059	0,074	0,019	0,083
A19	0,126	0,100	0,126	0,000	0,000	0,067
A20	0,074	0,128	0,111	0,167	0,080	0,128

Table 16. Rankings of UCA by the values of π_i^* utilizing the AW method

UCA	Way 1		Way 2		Way 3	
	π_i^*	Rank	π_i^*	Rank	π_i^*	Rank
A1	0,144	10	0,431	9	0,431	9
A2	0,137	8	0,395	4	0,419	8
A3	0,070	1	0,230	1	0,226	1
A4	0,227	20	0,707	19	0,704	20
A5	0,134	7	0,424	7	0,411	6
A6	0,131	5	0,425	8	0,404	5
A7	0,162	15	0,579	16	0,525	15
A8	0,197	17	0,574	15	0,608	17
A9	0,148	11	0,482	11	0,463	12
A10	0,148	12	0,498	12	0,466	13
A11	0,149	13	0,520	13	0,456	11
A12	0,100	3	0,300	2	0,331	3
A13	0,186	16	0,611	17	0,589	16
A14	0,113	4	0,401	5	0,340	4
A15	0,160	14	0,543	14	0,473	14
A16	0,081	2	0,324	3	0,249	2
A17	0,207	18	0,626	18	0,643	18
A18	0,143	9	0,478	10	0,442	10
A19	0,133	6	0,422	6	0,419	7
A20	0,221	19	0,721	20	0,688	19

The correlation analysis of the rankings of UCA by the values of π_i^* utilizing the AW method is presented in Table 17.

Table 17. Correlation analysis of the ranking of UCA by the values of π_i^* utilizing the AW method

	Way 1	Way 2	Way 3
Way 1	1		
Way 2	0,971	1	
Way 3	0,992	0,967	1

The computations using SW method are presented in Tables 18 – 20.

Table 18. Values of z_{ij} utilizing the SW-Way 1 technique

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,109	0,020	0,043	0,054	0,050	0,025
A2	0,102	0,030	0,039	0,070	0,028	0,040
A3	0,109	0,058	0,030	0,060	0,061	0,057
A4	0,119	0,003	0,019	0,027	0,034	0,015
A5	0,114	0,030	0,039	0,070	0,011	0,045
A6	0,119	0,045	0,027	0,070	0,028	0,030
A7	0,139	0,045	0,006	0,027	0,021	0,040
A8	0,102	0,020	0,034	0,004	0,055	0,025
A9	0,119	0,045	0,030	0,027	0,034	0,035
A10	0,124	0,040	0,027	0,054	0,004	0,045
A11	0,134	0,015	0,039	0,011	0,055	0,030
A12	0,152	0,058	0,012	0,048	0,021	0,052
A13	0,124	0,036	0,015	0,004	0,049	0,025
A14	0,129	0,030	0,043	0,054	0,041	0,030
A15	0,139	0,025	0,039	0,070	0,011	0,003
A16	0,146	0,058	0,027	0,060	0,055	0,020
A17	0,109	0,052	0,030	0,004	0,011	0,020
A18	0,124	0,020	0,030	0,040	0,055	0,030
A19	0,114	0,025	0,015	0,070	0,061	0,035
A20	0,129	0,015	0,019	0,004	0,034	0,015

Table 19. Values of z_{ij} utilizing the SW-Way 2 technique

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,009	0,058	0,135	0,166	0,145	0,064
A2	0,008	0,087	0,122	0,216	0,081	0,104
A3	0,009	0,166	0,094	0,186	0,180	0,150
A4	0,012	0,008	0,058	0,083	0,099	0,040
A5	0,010	0,087	0,122	0,216	0,033	0,117
A6	0,012	0,129	0,083	0,216	0,081	0,078
A7	0,027	0,129	0,019	0,083	0,062	0,104
A8	0,008	0,058	0,105	0,011	0,161	0,064
A9	0,012	0,129	0,094	0,083	0,099	0,092
A10	0,014	0,115	0,083	0,166	0,011	0,117
A11	0,021	0,044	0,122	0,034	0,161	0,078
A12	0,154	0,166	0,036	0,147	0,062	0,135
A13	0,014	0,102	0,047	0,011	0,143	0,064
A14	0,017	0,087	0,135	0,166	0,121	0,078
A15	0,027	0,071	0,122	0,216	0,033	0,007
A16	0,051	0,166	0,083	0,186	0,161	0,052
A17	0,009	0,150	0,094	0,011	0,033	0,052
A18	0,014	0,058	0,094	0,125	0,161	0,078
A19	0,010	0,071	0,047	0,216	0,180	0,092
A20	0,017	0,044	0,058	0,011	0,099	0,040

Table 20. Values of z_{ij} utilizing the SW-Way 3 technique

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,023	0,053	0,135	0,163	0,143	0,060
A2	0,000	0,083	0,120	0,216	0,075	0,102
A3	0,023	0,166	0,087	0,184	0,180	0,150
A4	0,052	0,000	0,045	0,076	0,094	0,035
A5	0,038	0,083	0,120	0,216	0,023	0,115
A6	0,052	0,127	0,075	0,216	0,075	0,075
A7	0,115	0,127	0,000	0,076	0,054	0,102
A8	0,000	0,053	0,100	0,000	0,159	0,060
A9	0,052	0,127	0,087	0,076	0,094	0,090
A10	0,069	0,113	0,075	0,163	0,000	0,115
A11	0,100	0,038	0,120	0,024	0,159	0,075
A12	0,154	0,166	0,020	0,143	0,054	0,135
A13	0,069	0,099	0,033	0,000	0,140	0,060
A14	0,086	0,083	0,135	0,163	0,117	0,075
A15	0,115	0,066	0,120	0,216	0,023	0,000
A16	0,137	0,166	0,075	0,184	0,159	0,048
A17	0,023	0,149	0,087	0,000	0,023	0,048
A18	0,069	0,053	0,087	0,120	0,159	0,075
A19	0,038	0,066	0,033	0,216	0,180	0,090
A20	0,086	0,038	0,045	0,000	0,094	0,035

Table 21. Values of z_j^* using SW method

Normalization	g_1	g_2	g_3	g_4	g_5	g_6
Way 1	0,152	0,058	0,043	0,070	0,061	0,057
Way 2	0,154	0,166	0,135	0,216	0,180	0,150
Way 3	0,154	0,166	0,135	0,216	0,180	0,150

Table 22. Rankings of UCA by the values of π_i utilizing the SW method

UCA	Way 1		Way 2		Way 3	
	π_i	Rank	π_i	Rank	π_i	Rank
A1	0,300	9	0,577	9	0,576	9
A2	0,309	8	0,618	4	0,595	7
A3	0,376	1	0,784	1	0,789	1
A4	0,216	20	0,300	19	0,302	19
A5	0,309	7	0,584	8	0,594	8
A6	0,318	6	0,599	7	0,619	6
A7	0,278	15	0,425	15	0,474	15
A8	0,239	17	0,407	16	0,373	17
A9	0,290	12	0,510	11	0,526	13
A10	0,293	11	0,506	12	0,534	12
A11	0,285	14	0,460	14	0,516	14
A12	0,342	3	0,700	2	0,672	3
A13	0,252	16	0,381	17	0,401	16
A14	0,328	4	0,603	6	0,658	4
A15	0,287	13	0,476	13	0,540	11
A16	0,366	2	0,699	3	0,769	2
A17	0,226	18	0,350	18	0,330	18
A18	0,300	10	0,529	10	0,562	10
A19	0,321	5	0,617	5	0,622	5
A20	0,216	19	0,269	20	0,297	20

The correlation analysis of the rankings of UCA by the values of π_i utilizing the SW method is presented in Table 23.

Table 23. Correlation analysis of the rankings of UCA by the values of π_i utilizing the AW method

	Way 1	Way 2	Way 3
Way 1	1		
Way 2	0,977	1	
Way 3	0,992	0,980	1

Equation (12) is used to calculate the distance (d_{ij}) from the reference ideal solution (z_j^*). The results are presented in Tables 24-26. The ranking results of UCA by the values of π_i^* utilizing the SW method are presented in Table 27.

Table 24. Distance values (d_{ij}) from the reference ideal solution (z_j^*) utilizing the SW-Way 1 technique

UCAVs	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,043	0,037	0,000	0,016	0,012	0,033
A2	0,050	0,028	0,004	0,000	0,034	0,017
A3	0,043	0,000	0,013	0,010	0,000	0,000
A4	0,033	0,055	0,025	0,043	0,028	0,042
A5	0,038	0,028	0,004	0,000	0,050	0,013
A6	0,033	0,013	0,017	0,000	0,034	0,027
A7	0,013	0,013	0,037	0,043	0,040	0,017
A8	0,050	0,037	0,010	0,066	0,007	0,033
A9	0,033	0,013	0,013	0,043	0,028	0,022
A10	0,028	0,018	0,017	0,016	0,058	0,013
A11	0,018	0,042	0,004	0,059	0,007	0,027
A12	0,000	0,000	0,032	0,022	0,040	0,005
A13	0,028	0,022	0,028	0,066	0,013	0,033
A14	0,022	0,028	0,000	0,016	0,020	0,027
A15	0,013	0,033	0,004	0,000	0,050	0,055
A16	0,005	0,000	0,017	0,010	0,007	0,037
A17	0,043	0,005	0,013	0,066	0,050	0,037
A18	0,028	0,037	0,013	0,029	0,007	0,027
A19	0,038	0,033	0,028	0,000	0,000	0,022
A20	0,022	0,042	0,025	0,066	0,028	0,042

Table 25. Distance values (d_{ij}) from the reference ideal solution (z_j^*) utilizing the SW-Way 2 technique

UCA	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,145	0,107	0,000	0,050	0,035	0,085
A2	0,146	0,079	0,013	0,000	0,099	0,045
A3	0,145	0,000	0,041	0,030	0,000	0,000
A4	0,143	0,158	0,077	0,132	0,081	0,110
A5	0,144	0,079	0,013	0,000	0,147	0,033
A6	0,143	0,036	0,052	0,000	0,099	0,071
A7	0,127	0,036	0,116	0,132	0,118	0,045
A8	0,146	0,107	0,030	0,204	0,019	0,085
A9	0,143	0,036	0,041	0,132	0,081	0,057
A10	0,141	0,050	0,052	0,050	0,169	0,033
A11	0,134	0,121	0,013	0,182	0,019	0,071
A12	0,000	0,000	0,099	0,069	0,118	0,014
A13	0,141	0,063	0,088	0,204	0,037	0,085
A14	0,137	0,079	0,000	0,050	0,059	0,071
A15	0,127	0,094	0,013	0,000	0,147	0,143
A16	0,103	0,000	0,052	0,030	0,019	0,097
A17	0,145	0,016	0,041	0,204	0,147	0,097
A18	0,141	0,107	0,041	0,091	0,019	0,071
A19	0,144	0,094	0,088	0,000	0,000	0,057
A20	0,137	0,121	0,077	0,204	0,081	0,110

Table 26. Distance values (d_{ij}) from the reference ideal solution (z_j^*) utilizing the SW-Way 3 technique

UCAVs	g_1	g_2	g_3	g_4	g_5	g_6
A1	0,132	0,113	0,000	0,053	0,037	0,090
A2	0,154	0,083	0,015	0,000	0,105	0,048
A3	0,132	0,000	0,048	0,032	0,000	0,000
A4	0,103	0,166	0,090	0,139	0,086	0,115
A5	0,117	0,083	0,015	0,000	0,157	0,035
A6	0,103	0,038	0,060	0,000	0,105	0,075
A7	0,040	0,038	0,135	0,139	0,126	0,048
A8	0,154	0,113	0,035	0,216	0,021	0,090
A9	0,103	0,038	0,048	0,139	0,086	0,060
A10	0,086	0,053	0,060	0,053	0,180	0,035
A11	0,055	0,127	0,015	0,192	0,021	0,075
A12	0,000	0,000	0,115	0,072	0,126	0,015
A13	0,086	0,066	0,102	0,216	0,040	0,090
A14	0,069	0,083	0,000	0,053	0,063	0,075
A15	0,040	0,099	0,015	0,000	0,157	0,150
A16	0,017	0,000	0,060	0,032	0,021	0,102
A17	0,132	0,016	0,048	0,216	0,157	0,102
A18	0,086	0,113	0,048	0,096	0,021	0,075
A19	0,117	0,099	0,102	0,000	0,000	0,060
A20	0,069	0,127	0,090	0,216	0,086	0,115

Table 27. Rankings of UCA by the values of π_i^* utilizing the SW method

UCA	Way 1		Way 2		Way 3	
	π_i^*	Rank	π_i^*	Rank	π_i^*	Rank
A1	0,141	9	0,423	9	0,424	9
A2	0,133	8	0,382	4	0,405	7
A3	0,065	1	0,216	1	0,211	1
A4	0,225	20	0,700	19	0,698	19
A5	0,132	7	0,416	8	0,406	8
A6	0,124	6	0,401	7	0,381	6
A7	0,163	15	0,575	15	0,526	15
A8	0,202	17	0,593	16	0,627	17
A9	0,151	12	0,490	11	0,474	13
A10	0,148	11	0,494	12	0,466	12
A11	0,157	14	0,540	14	0,484	14
A12	0,100	3	0,300	2	0,328	3
A13	0,190	16	0,619	17	0,599	16
A14	0,113	4	0,397	6	0,342	4
A15	0,155	13	0,524	13	0,460	11
A16	0,076	2	0,301	3	0,231	2
A17	0,215	18	0,650	18	0,670	18
A18	0,142	10	0,471	10	0,438	10
A19	0,121	5	0,383	5	0,378	5
A20	0,225	19	0,731	20	0,703	20

The correlation analysis of the rankings of UCA by the values of π_i^* utilizing the SW method is presented in Table 28.

Table 28. Correlation analysis of the ranking of UCA by the values of π_i^* utilizing the SW method

	Way 1	Way 2	Way 3
Way 1	1		
Way 2	0,971	1	
Way 3	0,992	0,967	1

Conclusively, PARIS model integrated with the objective criteria weight methods (AW, SW, EW) was applied to the unmanned combat aircraft (UCA) selection problem by following the proposed MCDM procedure. The results of the procedural computations indicate a relatively stable ranking order patterns of alternatives. After analyzing the results, the unmanned combat aircraft (UCA) a_3 was selected as the best candidate for the Air Force.

IV. CONCLUSION

In this paper, for the selection of unmanned combat aircraft (UCA), PARIS method based on MCDM theory is proposed to solve multiple criteria decision-making problems characterized by uncertain human judgments. To demonstrate the effectiveness of the proposed PARIS method, a case study was considered to evaluate and compare the quality of twenty unmanned combat aircraft (UCA). This study helps defense decision makers in the selection of unmanned combat aircraft to know the requirements of UCA and the priority of increasing their defense capabilities.

Given that in some cases it is difficult to determine the exact values of the attributes, and their values are considered as fuzzy data. A numerical approximation based on the fuzzy conversion scale (11-point scale) approach was proposed to systematically convert linguistic concepts into their corresponding fuzzy numbers.

As fuzzy sets are efficient to deal with uncertainty available in the information provided by the decision maker, PARIS is expanded for fuzzy sets to determine the most preferred choice among all possible options when the data is uncertain and imprecise. Here, the ratings of the alternatives are taken as fuzzy crisp values from the fuzzy conversion scale (11-point scale). In this approach, a weighted normalized Euclidean distance measure is also considered to calculate the distance of an alternative from the ideal solution. In complicated problems requiring uncertain decision-making, the PARIS technique produces consistent decision solutions. MCDM problems can be addressed using the proposed PARIS technique.

REFERENCES

- [1] Ardil, C., Bilgen, S. (2017). Online Performance Tracking. SocioEconomic Challenges, 1(3), 58-72. ISSN (print) – 2520-6621.
- [2] Ardil, C. (2021). Airline Quality Rating Using PARIS and TOPSIS in Multiple Criteria Decision Making Analysis. *International Journal of Industrial and Systems Engineering*, 15(12), 516 - 523.
- [3] Burney, S. , Jilani, T. , Ardil, C. (2007). A Comparison of First and Second Order Training Algorithms for Artificial Neural Networks. *International Journal of Computer and Information Engineering*, 1(1), 145 - 151.
- [4] Dyer, J.S. (2016). Multiattribute Utility Theory (MAUT). In: Greco, S., Ehrgott, M., Figueira, J. (eds) Multiple Criteria Decision Analysis. *International Series in Operations Research & Management Science*, vol 233. Springer, New York, NY. https://doi.org/10.1007/978-1-4939-3094-4_8.
- [5] Saaty, T. L. (1990). How to make a decision: The Analytic Hierarchy Process. *European Journal of Operational Research*, 48(1), 9-26. doi: 10.1016/0377-2217(90)90057-1
- [6] Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International Journal of Services Sciences*, 1(1), 83-98. doi: 10.1504/IJSSCI.2008.017590
- [7] Saaty, T.L. (1980). Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill, New York.

- [8] Buckley, J.J. (1985). Fuzzy hierarchical analysis, *Fuzzy Sets and Systems*, 17, 233–247.
- [9] Hwang, C.L.; Yoon, K. (1981). Multiple Attribute Decision Making: Methods and Applications. New York: Springer-Verlag.
- [10] Chu, T.C. (2002). Facility location selection using fuzzy TOPSIS under group decisions, *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, Vol. 10 No. 6, pp. 687-701.
- [11] Opricovic, S. (2007). A fuzzy compromise solution for multicriteria problems. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, 15(3), 363–380.
- [12] Opricovic, S., Tzeng, G.-H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research*, 156(2), 445–455.
- [13] Brans J.P., Mareschal B. (2005). Promethee Methods. In: Multiple Criteria Decision Analysis: State of the Art Surveys. *International Series in Operations Research & Management Science*, vol 78, pp 163-186. Springer, New York, NY. https://doi.org/10.1007/0-387-23081-5_5.
- [14] Brans, J., Ph. Vincke. (1985). A Preference Ranking Organisation Method: (The PROMETHEE Method for Multiple Criteria Decision-Making). *Management Science*, 31(6), 647-656.
- [15] Brans, J.P., Macharis, C., Kunsch, P.L., Chevalier, A., Schwaninger, M., (1998). Combining multicriteria decision aid and system dynamics for the control of socio-economic processes. An iterative real-time procedure. *European Journal of Operational Research* 109, 428-441.
- [16] Brans, J.P., Vincke, Ph., Mareschal, B., (1986). How to select and how to rank projects: the PROMETHEE method. *European Journal of Operational Research*, 24, 228-238.
- [17] Roy, B. (1991). The outranking approach and the foundation of ELECTRE methods. *Theory and Decision*, 31(1), 49–73.
- [18] Fei, L., Xia, J., Feng, Y., Liu, L. (2019) An ELECTRE-Based Multiple Criteria Decision Making Method for Supplier Selection Using Dempster-Shafer Theory. *IEEE Access*, 7, 84701-84716.
- [19] Zadeh L.A., (1965). Fuzzy Sets. *Information and Control*, 8, 338-353.
- [20] Atanassov. K.T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets Syst* 20(1):87–96.
- [21] Yager, R.R. (2013). Pythagorean fuzzy subsets. *Joint IFSA World Congress and NAFIPS Annual Meeting (IFSA/NAFIPS)* 57–61 6.
- [22] Yager, R. R. (2013). Pythagorean membership grades in multi-criteria decision making. *IEEE Trans Fuzzy Syst* 22(4):958–965.
- [23] Yager, R. R. (2017). Generalized orthopair fuzzy sets. *IEEE Transactions on Fuzzy Systems*, 25(5), 1222– 1230.
- [24] Tian, X., Niu, M., Zhang, W., Li, L., Herrera-Viedma, E. (2021). A novel TODIM based on prospect theory to select green supplier with q-rung orthopair fuzzy set. *Technological and Economic Development of Economy*, 27(2), 284-310.
- [25] Cuong, B. C., Kreinovich, V. (2013). Picture Fuzzy Sets - a new concept for computational intelligence problems. Departmental Technical Reports (CS). 809. In *Proceedings of the Third World Congress on Information and Communication Technologies WICT'2013*, Hanoi, Vietnam, December 15-18, 2013, pp. 1-6.
- [26] Cuong, B. C. (2014). Picture Fuzzy Sets. *Journal of Computer Science and Cybernetics*, V.30, N.4 (2014), 409–420.
- [27] Gundogdu, FK, Kahraman, C. (2019). Spherical fuzzy sets and spherical fuzzy TOPSIS method. *J Intell Fuzzy Syst* 36(1):337–352.
- [28] Mahmood, T.; Ullah, K.; Khan, Q.; Jan, N. An approach toward decision-making and medical diagnosis problems using the concept of spherical fuzzy sets. *Neural Comput Appl*. 2018, 1–13.
- [29] Ullah, K., Mahmood, T., Jan, N. (2018). Similarity Measures for T-Spherical Fuzzy Sets with Applications in Pattern Recognition. *Symmetry*, 10(6), 193.
- [30] Smarandache, F. (2003). A unifying field in logics neutrosophic logic. Neutrosophy, neutrosophic set, neutrosophic probability. (3rd ed.). Xiquan, Phoenix: American Research Press.
- [31] Smarandache, F. (2003). Neutrosophic Logic - Generalization of the Intuitionistic Fuzzy Logic. <https://arxiv.org/abs/math/0303009>
- [32] Ardil, C. (2023). Unmanned Combat Aircraft Selection using Fuzzy Proximity Measure Method in Multiple Criteria Group Decision Making. *International Journal of Computer and Systems Engineering*, 17(3), 238 - 245.
- [33] Ardil, C. (2023). Fuzzy Multiple Criteria Decision Making for Unmanned Combat Aircraft Selection Using Proximity Measure Method. *International Journal of Computer and Information Engineering*, 17(3), 193 - 200.

- [34] Ardil, C. (2022). Multiple Criteria Decision Making for Turkish Air Force Stealth Fighter Aircraft Selection. *International Journal of Aerospace and Mechanical Engineering*, 16(12), 369 - 374.
- [35] Ardil, C. (2022). Fuzzy Uncertainty Theory for Stealth Fighter Aircraft Selection in Entropic Fuzzy TOPSIS Decision Analysis Process. *International Journal of Aerospace and Mechanical Engineering*, 16(4), 93 - 102.
- [36] Ardil, C. (2022). Vague Multiple Criteria Decision Making Analysis Method for Fighter Aircraft Selection. *International Journal of Aerospace and Mechanical Engineering*, 16(5), 133-142.
- [37] Ardil, C. (2022). Military Attack Helicopter Selection Using Distance Function Measures in Multiple Criteria Decision Making Analysis. *International Journal of Aerospace and Mechanical Engineering*, 16(2), 20 - 27.
- [38] Ardil, C. (2022). Fighter Aircraft Selection Using Neutrosophic Multiple Criteria Decision Making Analysis. *International Journal of Computer and Systems Engineering*, 16(1), 5 - 9.
- [39] Ardil, C. (2022). Fighter Aircraft Selection Using Fuzzy Preference Optimization Programming (POP). *International Journal of Aerospace and Mechanical Engineering*, 16(10), 279 - 290.
- [40] Ardil, C. (2022). Aircraft Selection Using Preference Optimization Programming (POP). *International Journal of Aerospace and Mechanical Engineering*, 16(11), 292 - 297.
- [41] Ardil, C. (2022). Aircraft Selection Problem Using Decision Uncertainty Distance in Fuzzy Multiple Criteria Decision Making Analysis. *International Journal of Mechanical and Industrial Engineering*, 16(3), 62 - 69.
- [42] Ardil, C. (2021). Neutrosophic Multiple Criteria Decision Making Analysis Method for Selecting Stealth Fighter Aircraft. *International Journal of Aerospace and Mechanical Engineering*, 15(10), 459 - 463.
- [43] Ardil, C. (2021). Military Combat Aircraft Selection Using Trapezoidal Fuzzy Numbers with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). *International Journal of Computer and Information Engineering*, 15(12), 630 - 635.
- [44] Ardil, C. (2021). Freighter Aircraft Selection Using Entropic Programming for Multiple Criteria Decision Making Analysis. *International Journal of Mathematical and Computational Sciences*, 15(12), 125 - 132.
- [45] Ardil, C. (2021). Fighter Aircraft Evaluation and Selection Process Based on Triangular Fuzzy Numbers in Multiple Criteria Decision Making Analysis Using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). *International Journal of Computer and Systems Engineering*, 15(12), 402 - 408.
- [46] Ardil, C. (2021). Comparison of Composite Programming and Compromise Programming for Aircraft Selection Problem Using Multiple Criteria Decision Making Analysis Method. *International Journal of Aerospace and Mechanical Engineering*, 15(11), 479 - 485.
- [47] Ardil, C. (2021). Advanced Jet Trainer and Light Attack Aircraft Selection Using Composite Programming in Multiple Criteria Decision Making Analysis Method. *International Journal of Aerospace and Mechanical Engineering*, 15(12), 486 - 491.
- [48] Ardil, C. (2020). Trainer Aircraft Selection Using Preference Analysis for Reference Ideal Solution (PARIS). *International Journal of Aerospace and Mechanical Engineering*, 14(5), 195 - 209.
- [49] Ardil, C. (2020). Regional Aircraft Selection Using Preference Analysis for Reference Ideal Solution (PARIS). *International Journal of Transport and Vehicle Engineering*, 14(9), 378 - 388.
- [50] Ardil, C. (2020). Aircraft Selection Process Using Preference Analysis for Reference Ideal Solution (PARIS). *International Journal of Aerospace and Mechanical Engineering*, 14(3), 80 - 93.
- [51] Ardil, C. (2020). A Comparative Analysis of Multiple Criteria Decision Making Analysis Methods for Strategic, Tactical, and Operational Decisions in Military Fighter Aircraft Selection. *International Journal of Aerospace and Mechanical Engineering*, 14(7), 275 - 288.
- [52] Ardil, C. (2019). Military Fighter Aircraft Selection Using Multiplicative Multiple Criteria Decision Making Analysis Method. *International Journal of Mathematical and Computational Sciences*, 13(9), 184 - 193.
- [53] Ardil, C. (2019). Fighter Aircraft Selection Using Technique for Order Preference by Similarity to Ideal Solution with Multiple Criteria Decision Making Analysis. *International Journal of Transport and Vehicle Engineering*, 13(10), 649 - 657.
- [54] Ardil, C. (2019). Aircraft Selection Using Multiple Criteria Decision Making Analysis Method with Different Data Normalization Techniques. *International Journal of Industrial and Systems Engineering*, 13(12), 744 - 756.
- [55] Ardil, C., Pashaev, A., Sadiqov, R., Abdullayev, P. (2019). Multiple Criteria Decision Making Analysis for Selecting and Evaluating Fighter Aircraft. *International Journal of Transport and Vehicle Engineering*, 13(11), 683 - 694.
- [56] Ardil, C. (2020). Aircraft Selection Process Using Preference Analysis for Reference Ideal Solution (PARIS). *International Journal of Aerospace and Mechanical Engineering*, 14(3), 80 - 93.
- [57] Ardil, C. (2020). Trainer Aircraft Selection Using Preference Analysis for Reference Ideal Solution (PARIS). *International Journal of Aerospace and Mechanical Engineering*, 14(5), 195 - 209.
- [58] Ardil, C. (2020). A Comparative Analysis of Multiple Criteria Decision Making Analysis Methods for Strategic, Tactical, and Operational Decisions in Military Fighter Aircraft Selection. *International Journal of Aerospace and Mechanical Engineering*, 14(7), 275 - 288.
- [59] Ardil, C. (2020). Regional Aircraft Selection Using Preference Analysis for Reference Ideal Solution (PARIS). *International Journal of Transport and Vehicle Engineering*, 14(9), 378 - 388.
- [60] Ardil, C. (2021). Airline Quality Rating Using PARIS and TOPSIS in Multiple Criteria Decision Making Analysis. *International Journal of Industrial and Systems Engineering*, 15(12), 516 - 523.
- [61] Le, H. K. (2022). Multi-Criteria Decision Making in the Milling Process Using the PARIS Method. *Eng. Technol. Appl. Sci. Res.*, vol. 12, no. 5, pp. 9208-9216.
- [62] Chen, S., Hwang, C. (1992). Fuzzy Multiple Attribute Decision Making - Methods and Applications. Lecture notes in economics and mathematical systems, pp 289-486.