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Research Article

Unmanned Aerial Vehicle Selection Using Fuzzy Choquet Integral

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Abstract

Unmanned aerial vehicle (UAV) selection is not an easy decision as many alternatives and criteria must be evaluated at the same time. This selection decision requires the consideration of many different criteria including payload capacity, maximum speed, endurance, altitude, avionics systems, price, economic life, and maximum range. The main aim of this study is to decide the most appropriate UAV by considering these criteria. The fuzzy logic-based fuzzy Choquet integral methodology is used to select this vehicle which allows decision-makers to define references as linguistic and in interval range. A numerical example is presented to analyze the applicability of the proposed approach. The proposed approach resulted in a successful application by comparing different UAVs and the most appropriate vehicle is selected at the final stage.

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Bulanık Choquet Integral Yöntemini Kullanarak İnsansız Hava Aracı Seçimi

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Öz

İnsansız hava aracı (İHA) seçimi birçok alternatif ve kriterin aynı anda değerlendirilmesi gerektiği için kolay bir karar değildir. Bu seçim kararı için yükleme kapasitesi, maksimum hız, dayanıklılık, yükseklik, aviyonik sistemler, fiyat, ekonomik süre ve maksimum mesafe kriterleri dikkate alınmalıdır. Bu çalışmanın temel amacı bu kriterler dikkate alınarak en uygun İHA'ya karar vermektir. Karar vericinin kriterleri dilsel ve aralıklı değerler olarak tanımlamasına izin veren bu yöntem için bulanık mantık tabanlı bulanık Choquet integral yöntemi kullanılmıştır. Önerilen yöntemin uygulanabilirliğini analiz etmek için sayısal bir örnek sunulmuştur. Önerilen yaklaşım, farklı İHA'ları karşılaştırarak başarılı bir uygulama ile sonuçlanmış ve son aşamada en uygun araç seçilmiştir.

1. INTRODUCTION

Unmanned aerial vehicle (UAV), commonly known as a drone, is a type of remotely controlled aircraft. UAVs are divided into two groups as airplanes that fly by remote control or that can move automatically on a specific flight plan. While remotely controlled UAVs are controlled by pilot intervention from ground stations, UAVs with a flight plan can directly perform their duties on the relevant coordinate and return to the relevant base.

UAVs are economical and advantageous in terms of personnel. In terms of economic advantage, it is more affordable than other aircraft. Especially when looking at the unit cost of large warplanes, it is seen that the price of UAVs is appropriate. In terms of personnel advantage, UAVs need fewer than fighter aircraft. In terms of post-use maintenance, repair, and administration, the need can be met with fewer than fighter jets. One of the other advantages of UAVs is that they have longer air time. The ability of UAVs to fly without a pilot is directly proportional to their stay in the air. The warplanes used by the pilot can stay in the air for a certain time because the pilot can manage for a certain period. Therefore, the fact that unmanned aerial vehicles do not physically need a pilot, that is, they can be controlled by more than one pilot from the control station on the ground, is seen as one of the most important advantages. UAVs are more advantageous not only when purchasing but also when using them. Preparation, removal, and post-landing maintenance of a warplane is much more than UAV. Therefore, UAVs are less costly in this regard.

UAVs, which we have started to see more in recent years and increasing their importance day by day, are used in many areas and these areas of use are increasing day by day. Some of these areas are reconnaissance and surveillance, ensuring the security of the open seas, meteorological research, neutralizing enemy air defenses, exploring the landing area before the amphibious operation, damage detection in natural disasters, preventing human trafficking, and target marking in wars.

Many studies on aircraft selection are proposed in the literature. If we look at the methods used in these studies, Even Swaps Method [1], five-step approach method [2], NAIADE Method [3], Analytical Hierarchy (AHP) method [4,5], Fuzzy set theory method [6], Fuzzy logic and Even Swaps Method [7], Fuzzy AHP [8], TOPSIS method [9], AHP, COPRAS, and MOORA method [10], Analytical Hierarch Process (AHP) and TOPSIS method [11], Fuzzy Reference Ideal Method (FRIM) [12], Heuristics [13], fuzzy AHP and efficacy method [14], Apply the Additive Ratio Assessment (ARAS) and Full Consistency Method (FUCOM) [15] have all been used for the selection, evaluation or ranking of aircraft types with different specifications and sizes. Besides, a fuzzy methodology [16] is proposed for a healthcare facility location selection problem [17]. As for the Choquet integral methodology literature, fuzzy Choquet integral is used in thermal power plant selection [18], ERP software selection [19], sustainable energy plan [20], assess software quality [21], partner and configuration selection [22], continuous shapely operations [23], customer preference analysis [24], software development risk assessment [25], selection of transportation alternatives [26] and selection of smart medical device [27].

As can be seen in the above-mentioned studies, the fuzzy Choquet integral has not been used before in the studies on plane selection as well as UAV selection. Besides, the selection of unmanned aircraft rather than aircraft selection in this study is a difference of the study, and the other difference is that the fuzzy Choquet integral method has not been applied in this field before. This has meant to fill an important gap in the fuzzy Choquet integral literature. Thanks to the fuzzy Choquet integral method, decision-makers can make more flexible decisions by using linguistic expressions for each criterion rather than precise expressions in UAV selection. This flexibility arises from the fact that the method allows the decision-maker to make decisions within a certain range. Thus, the errors that arise in the case of subjective decision-making will be eliminated. Although this methodology involves a large number of calculations, it is an outstanding multi-attribute method for problems with fuzzy interactive attributes.

In this study, the subjective weight decisions are eliminated using the fuzzy Choquet integral approach. In the proposed approach, the decision-maker defines the references flexible as linguistic and in interval range for each criterion. This approach is applied to the UAV selection problem in this study by considering different criteria.

The rest of the study is organized as follows. Fuzzy Choquet integral method is explained in detail in Chapter 2. More information about the UAV definition is provided in Chapter 3. In Chapter 4, a numerical example for the UAV selection application is presented. Concluding remarks and future research studies are given in Chapter 5.

2. METHODOLOGY

2.1. Fuzzy Choquet Integral

Fuzzy Choquet integral methodology consists of different subtitles. These subtitles are fuzzy arithmetic, Choquet integral, generalized fuzzy Choquet integral, and generalized fuzzy Choquet integral algorithm. All these subtitles are detailed as follows.

2.1.1 Fuzzy Arithmetic

Let Z be a subset of R of real numbers in the universe of verbal expressions: In the fuzzy set B consisting of ordered pairs in Z = $\{z_1, z_2, ..., z_n\}$. Z, the membership function $\widetilde{B} = \{(x, \mu\widetilde{B}(z)) \mid z \in Z\}$, is expressed as follows:

$\mu\widetilde{B}(z) : Z \rightarrow [0, 1]$.

The average values of Ã fuzzy numbers, $\widetilde{B} = (b_1, b_2, b_3, b_4)$, is obtained from the following equation used to clarify the trapezoidal fuzzy numbers [28].

$$F(\tilde{B}) = \frac{b_1 + b_2 + b_3 + b_4}{4} \tag{1}$$

2.1.2 Choquet Integral

P(T) and T = $\{t_1, t_2, ..., t_n\}$ is a fuzzy measure g that is non-additive and has the following properties with T being the power set: P(T) → [0, 1].

A fuzzy measure g which is not additive and has the following properties with P (T) and T = $\{t_1, t_2, ..., t_n\}$ the power set of T: function is expressed as P (T) → [0, 1].

- (i) g (Ø) = 0;
- (ii) g (T) = 1;
- (iii) if B is C∈P(T) and $B \subset C$ then g (B) ≤ g (C);
- (iv) in the set P(T), if $B_1 \subset B_2 \subset B_3 \subset ...$ and $U_{i=1}^{\infty} B_i \in P(T)$ then $\lim_{i\to\infty} g(B_i) = g(U_{i=1}^{\infty} B_i)$;
- (v) in the set P(T), if $B_1 \supset B_2 \supset B_3 \supset ...$ and $\cap_{i=1}^{\infty} Bi \in P(T)$ then $\lim_{i\to\infty} g(B_i) = g(\cap_{i=1}^{\infty} B_i)$.

2.1.3 Generalized Fuzzy Choquet Integral

If it is accepted that g over T is a fuzzy measure; Choquet Integral $g_i = g(\{t_i\})$, $0 \le f(t_{1)}) \le f(t_{(2)}) \le ... \le$

$f(t_{(n)}) \leq 1$ and $f(t_0) = 0$ then it is seen that $f(t_{(i)})$, g_i and λ being a monotonously increasing function. The standard Choquet integral is generalized with the following cases [29].

Case 1. In the case of $\bar{f} \in \bar{F}(T)$ and $\bar{g} \in \bar{M}(T)$, the Choquet integral $\bar{f}$ corresponding to the fuzzy measure $\bar{g}$ with the interval number is calculated as follows.

$$(C)\int \bar{f}d\bar{g} = [(C)\int f^{-}dg^{-},\ (C)\int f^{+}dg^{+}] \quad (2)$$

Case 2. In the case of $\tilde{f} \in \tilde{F}(T)$ and $\tilde{g} \in \tilde{M}(T)$, it is possible to mention the following equation.

$$((C)\int \tilde{f}d\tilde{g})_{\propto} = \left[(C)\int f_{\propto}^{-}, dg_{\propto}^{-},\ (C)\int f_{\propto}^{+}, dg_{\propto}^{+}\right] \quad (3)$$

Case 3. In the case of $0 \leq \alpha_1 \leq \alpha_2 \leq \dots \leq \alpha_n \leq 1$ obtained, the expression is calculated as follows.

$$((C)\int \tilde{f}d\tilde{g})_{\propto_1} \supset ((C)\int \tilde{f}d\tilde{g})_{\propto_2} \supset \cdots \supset ((C)\int \tilde{f}d\tilde{g})_{\propto_n} \quad (4)$$

Case 4. The following equation is calculated by considering Case 2 and Case 4.

$$(C)\int \tilde{f}d\tilde{g} = ||_{\propto\in[0,1]}[(C)\int f_{\propto}^{-}, dg_{\propto}^{-}, (C)\int f_{\propto}^{+}, dg_{\propto}^{+}] \quad (5)$$

2.1.4 Generalized Fuzzy Choquet Integral Algorithm

In the algorithm where n_j is the total number of criteria and j is the number of main criteria. The steps of generalized fuzzy Choquet integral are as follows [30]:

Step 1. The determined i_{th} criterion, the degree of significance obtained from the verbal preferences of decision-makers (Table 1), the actual unmanned aerial vehicle performance, and the tolerance range of the expected unmanned aerial vehicle performance are investigated and the results are tabulated. By using the scale in Table 1, a decision-making criterion can be evaluated in a wide range. The wide range of the scale enables the decision-maker to make more flexible decisions for a criterion.

Step 2. Parameters where k, i=1, 2, ..., t=1, 2, 3, ... , n_j, j=1, 2, ... and k are the number of decision-makers, t is the decision-maker and i_{th} criterion, the fuzzy number $\tilde{p}_i^t$ is the actual unmanned aerial vehicle performance, the fuzzy number of $\tilde{A}_i^t$ is the degree of materiality and the $\tilde{e}_i^t$ the fuzzy number corresponds to the tolerance range of the expected unmanned aerial vehicle performance.

Step 3. Using equation (6), $\tilde{A}_i^t$, $\tilde{p}_i^t$ and $\tilde{e}_i^t$ are averaged and $\tilde{A}_i$, $\tilde{p}_i$ and $\tilde{e}_i$ values are founded respectively.

$$\tilde{A}_i = \frac{\sum_{t=1}^{k}\tilde{A}_i^t}{k} = \left[\frac{\sum_{t=1}^{k}\tilde{A}_{i1}^t}{k}, \frac{\sum_{t=1}^{k}\tilde{A}_{i2}^t}{k}, \frac{\sum_{t=1}^{k}\tilde{A}_{i3}^t}{k}, \frac{\sum_{t=1}^{k}\tilde{A}_{i4}^t}{k}\right] \quad (6)$$

Step 4. The effect of each criterion on unmanned aerial vehicle performance is normalized by equation (7) where $\tilde{f}_i \in \tilde{F}(S)$ is a fuzzy valued function.

$$\tilde{f}_i = ||_{\propto\in[0,1]} \bar{f}_i^{\propto} = ||_{\propto\in[0,1]} [f_{i,\propto}^{-}, f_{i,\propto}^{+}] \quad (7)$$

Step 5. The set of all fuzzy-valued $\tilde{f}$ functions become $\tilde{F}(S)$, and the following equation is obtained for all $\alpha \in [0,1]$ with the α-level segments of $\bar{p}_i^{\propto} i$ and $\bar{e}_i^{\propto}$.

$$\bar{f}_i^{\propto} = [f_{i,\propto}^{-}, f_{i,\propto}^{+}] = \frac{\bar{p}_i^{\propto} - \bar{e}_i^{\propto} + [1,1]}{2} \quad (8)$$

Step 6. Unmanned aerial vehicle performance is obtained by using equation (9) regarding the j_{th} criteria.

$$(C)\int \tilde{f}d\tilde{g} = ||_{\propto\in[0,1]}[(C)\int f_{\propto}^{-}, dg_{\propto}^{-}, (C)\int f_{\propto}^{+}, dg_{\propto}^{+}] \quad (9)$$

Step 7. The total unmanned aerial vehicle performance attained from all criteria is decreased to a fuzzy $\tilde{Y}$ by considering the two-stage hierarchical process of the generalized Choquet integral.

Step 8. If $\mu_{\tilde{Y}}(x)$ value is accepted as the membership of $\tilde{Y}$ and calculated by using equation (1), $\tilde{Y}$ the fuzzy number is clarified to the absolute value of y and the total performances of the unmanned aerial vehicles are compared.

3. UNMANNED AERIAL VEHICLES (UAVs)

UAVs are also defined as "drones" in the international literature and they mean the same except for certain technical features. On the other hand, UAVs that do not have as high technical features as today have been generally used for military purposes until today. However, UAVs are also used in the civil sector at present. Some of the applications of the civil sector are as follows:

- Dangerous missions in which UAVs are the only solution, such as bad weather and environmental conditions, nuclear, biological, and chemically contaminated areas, regions with radiation threat.

- Scientific tasks where UAVs are both the most economical and the best solution, such as forecasting, collecting data on the atmosphere and oceans, and surveillance for environmental, agricultural, magnetic, and radiological mapping purposes,

Table 1. Trapezoidal fuzzy numbers and verbal significance [31].

Low / High levels		**Significance degrees**		
Short-form	**Verbal expressions**	**Short-form**	**Verbal expressions**	**Trapezoidal fuzzy numbers**
TL	Too low	TIN	Too insignificant	(0, 0, 0, 0)
VL	Very low	VIN	Very insignificant	(0, 0.01, 0.02, 0.07)
L	Low	IN	Insignificant	(0.04, 0.1, 0.18, 0.23)
LL	Less Low	LIN	Less insignificant	(0.17, 0.22, 0.36, 0.42)
M	Middle	M	Middle	(0.32, 0.41, 0.58, 0.65)
LH	Less High	LIM	Less important	(0.58, 0.63, 0.8, 0.86)
H	High	IM	Important	(0.72, 0.78, 0.92, 0.97)
VH	Very High	VIM	Very important	(0.93, 0.98, 0.98, 1)
TH	Too high	TIM	Too important	(1, 1, 1, 1)

- Commercially preferred tasks of UAVs such as border security, traffic conditions of cities, regional air and base stations, surveillance of protected areas, fire, control of pipelines, and power transmission lines.

There are some criteria to be considered in performance evaluation, as UAVs are used for many purposes and vary widely. These criteria are stated below:

- *Payload capacity:* Units other than avionics, fuel, and equipment that ensure reliable take-off, flight, and landing of the aircraft and which are selected directly for the mission are called payload.

- *Maximum speed:* It varies according to the engine power of the aircraft. Speed values may be desired to be at the highest, lowest, or average values according to different operations.

- *Maximum endurance:* It refers to the maximum period that the aircraft can safely operate in the air with the amount of fuel it can use from the moment the aircraft leaves the runway.

- *Maximum altitude:* During its mission, the aircraft is not affected by simple air defense systems, not being noticed, and the increase in the radius at which it can receive images is related to the altitude at which it can rise.

- *Avionic systems:* These are systems installed on aircraft to perform individual functions along with communication, navigation, display, and management of multiple systems between the avionic systems of the aircraft.

- *Price:* It is the cost to be borne for a UAV as a result of the aircraft being included in the inventory. This cost includes ground equipment.

- *Economic life:* It refers to the period during which the aircraft can remain active in the system and benefit from it, provided that it is maintained.

- *Maximum range:* It is the farthest distance that the aircraft can be controlled by the pilot after taking off from the base where it is stationed, at the same time that it can go with the fuel and its load and return to its base safely.

4. NUMERICAL EXAMPLE

This section presents the application of the fuzzy Choquet integral methodology to a UAV selection problem faced by a decision-maker who is a head of purchasing department of a private company. This decision-maker first consulted with the knowledge of 3 aviation experts to create the starting matrix. Based on the opinion of each expert, a common starting matrix was prepared and shown in Table 3. The decision-maker tries to decide the most appropriate UAV by considering different criteria. The decision-maker has determined eight criteria for selecting the most suitable UAV as shown in Figure 1.

The hierarchical structure for the criteria is also given in Figure 1. In Table 2, the abbreviations of the criteria determined for the aircraft used in the study are given. The criteria and alternatives in Table 3 are evaluated according to linguistic expressions using Table 1 mentioned in the previous section. The data according to the trapezoidal fuzzy numbers are given in Table 4.

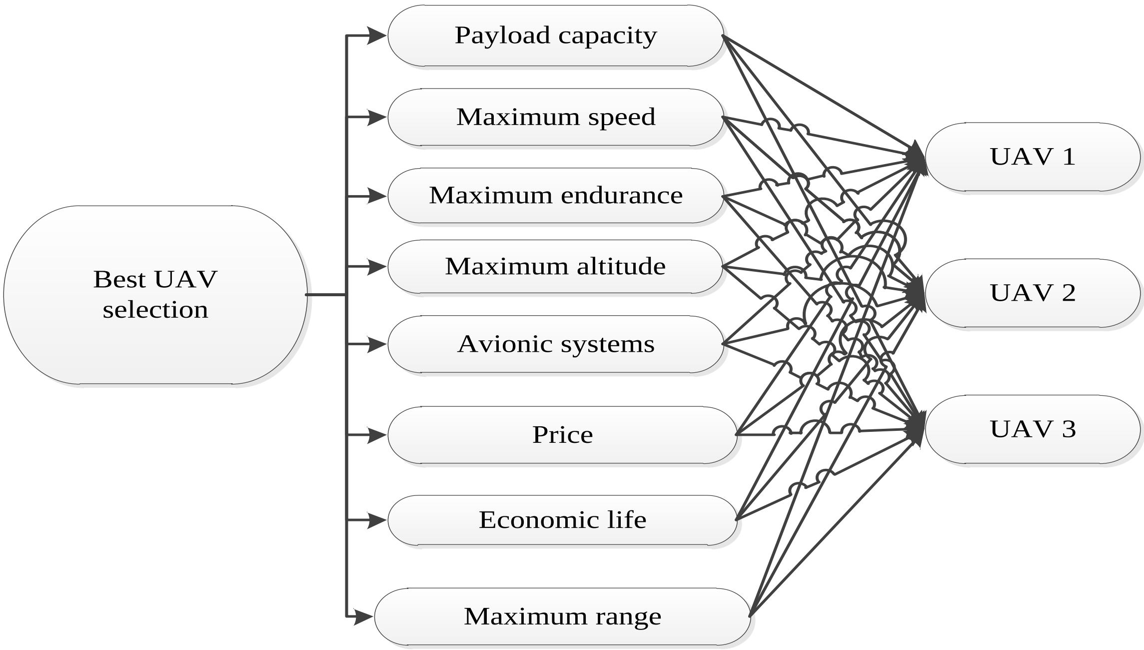

Figure 1. The hierarchy of the unmanned aerial vehicle selection problem.

Table 2. Linguistic representation of unmanned aerial vehicle selection criteria.

Criteria	Criteria short form	Criteria parameter
Payload capacity	PC	C_1
Maximum speed	MS	C_2
Maximum endurance	ME	C_3
Maximum altitude	MA	C_4
Avionic systems	AS	C_5
Price	P	C_6
Economic life	EL	C_7
Maximum range	MR	C_8

Table 3. Linguistic representation of criteria and alternatives.

Criteria	Individual importance of the criteria	The desired UAV tolerance range	Unmanned Aerial Vehicles (UAVs)		
			UAV-1	UAV-2	UAV-3
C_1: PC	VIM	(IM, VIM)	TH	LH	H
C_2: MS	IM	(IM, TIM)	VH	H	LH
C_3: ME	VIM	(VIM, TIM)	TH	H	LH
C_4: MA	IM	(M, LIM)	H	VH	LH
C_5: AS	IM	(M, IM)	LH	M	H
C_6: P	IM	(M, VIM)	H	VH	H
C_7: EL	IM	(IM, TIM)	VH	H	LH
C_8: MR	VIM	(VIM, TIM)	TH	H	LH

By applying the algorithm steps, the two-step summation process of the generalized Choquet fuzzy integral was used and the findings obtained from the values of three unmanned aerial vehicles were calculated. Total performances of UAVs are provided in Table 5. For UAV-1, the fuzzy Choquet integral value at α=0 is found as follows:

$$\lambda = -0.99, g(A_{(1)}) = 1.0$$

and finally $(C)\int \overline{f}d\overline{g} = (0.499, 0.872)$

The UAV selection criteria, which were converted into trapezoidal fuzzy numbers with verbal expressions, were clarified as shown in Table 6 and the alternatives were listed by using Eq. (1) as follows:

$$F(\tilde{B}) = \frac{0.499 + 0.509 + 0.805 + 0.872}{4} = 0.671$$

Table 4. Criteria and alternatives representation according to trapezoidal fuzzy numbers.

Criteria	Individual significance of the criteria	Desired UAV tolerance range	Unmanned Aerial Vehicles (UAVs)		
			UAV-1	UAV-2	UAV-3
C_1	(0.93,0.98,0.98,1)	(0.72,0.78,0.98,1)	(1,1,1,1)	(0.58,0.63,0.8,0.86)	(0.72,0.78,0.92,0.97)
C_2	(0.72,0.78,0.92,0.97)	(0.72,0.78,1,1)	(0.93,0.98,0.98,1)	(0.72,0.78,0.92,0.97)	(0.58,0.63,0.8,0.86)
C_3	(0.93,0.98,0.98, 1)	(0.93,0.98,1,1)	(1,1,1,1)	(0.72,0.78,0.92,0.97)	(0.58,0.63,0.8,0.86)
C_4	(0.72,0.78,0.92,0.97)	(0.32,0.41,0.8,0.86)	(0.72,0.78,0.92,0.97)	(0.93,0.98,0.98,1)	(0.58,0.63,0.8,0.86)
C_5	(0.32,0.41,0.58,0.65)	(0.32,0.41,0.92,0.97)	(0.58,0.63,0.8,0.86)	(0.32,0.41,0.58,0.65)	(0.72,0.78,0.92,0.97)
C_6	(0.72,0.78,0.92,0.97)	(0.32,0.41,0.8,0.86)	(0.72,0.78,0.92,0.97)	(0.93,0.98, 0.98,1)	(0.58,0.63,0.8,0.86)
C_7	(0.72,0.78,0.92,0.97)	(0.72,0.78,1,1)	(0.93,0.98,0.98,1)	(0.72,0.78,0.92,0.97)	(0.58,0.63,0.8,0.86)
C_8	(0.93,0.98,0.98, 1)	(0.93,0.98, 1, 1)	(1,1,1,1)	(0.72,0.78,0.92,0.97)	(0.58,0.63,0.8,0.86)

Table 5. The total performance of unmanned aerial vehicles.

Criteria	Unmanned Aerial Vehicles (UAVs)		
	UAV-1	UAV-2	UAV-3
Total performance	(0.499,0.509,0.805,0.872)	(0.402,0.467,0.776, 0.831)	(0.425,0.489,0.838, 0.895)
C_1: PC	(0.5, 0.51, 0.61, 0.64)	(0.29, 0.325, 0.51, 0.57)	(0. 36, 0.4, 0.57, 0.625)
C_2: MS	(0 465, 0.49, 0.6, 0.64)	(0 36, 0.39, 0.57, 0.625)	(0.29, 0.315, 0.51, 0.57)
C_3: ME	(0.5, 0.5, 0.51, 0.535)	(0.36, 0.39, 0.47, 0.52)	(0.29, 0.315, 0.41, 0.465)
C_4: MA	(0.43, 0.49, 0.755, 0.825)	(0.535, 0.59, 0.785, 0.84)	(0 36, 0.415, 0.695, 0.77)
C_5: AS	(0.305,0.355, 0.695, 0.77)	(0. 175, 0.245,0.585, 0.665)	(0 375, 0.43, 0.755, 0.825)
C_6: PS	(0.29, 0.325, 0.585, 0.64)	(0.29, 0.325, 0.585, 0.64)	(0.082, 0.12, 0.365, 0.42)
C_7: EL	(0.375, 0.43,0.755, 0.825)	(0.1, 0.15, 0.475, 0.55)	(0.035, 0.09, 0.385, 0.455)
C_8: MR	(0.43, 0.49, 0.85, 0.9)	(0.23, 0.305, 0.68, 0.74)	(0.155, 0.21, 0.57, 0.625)

Table 6. Total performance results.

Criteria	Unmanned Aerial Vehicles (UAVs)		
	UAV-1	UAV-2	UAV-3
Total performance	0.671*	0.619	0.662
C_1: PC	0.450*	0.115	0.180
C_2: MS	0.146	0.189	0.645*
C_3: ME	0.149	0.435*	0.212
C_4: MA	0.418*	0.365	0.305
C_5: AS	0.358	0.417	0.499*
C_6: P	0.250	0.251*	0.125
C_7: EL	0.499*	0.250	0.221
C_8: MR	0.680*	0.117	0.214

As seen in Table 6, after the clarifying process, UAV 1 has been determined as the best unmanned aerial vehicle that satisfies the criteria at the highest level. UAV 3 was the second-best unmanned aerial vehicle and UAV 2 was the unmanned aerial vehicle that met the criteria least. Looking at the results at the criterion level, UAV 1 has been the best alternative in terms of Payload capacity, Maximum speed, Maximum endurance, Economic life, and Maximum range. UAV 2 was the best alternative in terms of Maximum altitude and Price, while UAV 3 was the best alternative for Avionic systems.

5. COMPARATIVE ANALYSIS SECTION

In this section, the UAV selection problem is also solved by using fuzzy TOPSIS methodology to compare fuzzy Choquet integral results and validation [32]. Euclidian distances from alternatives to negative and positive ideal solutions are considered in this approach. Relative closeness values of UAVs are measured and the UAV is proposed as the best UAV with the maximum relative closeness value.

Fuzzy TOPSIS steps were applied to the same problem considering the same fuzzy numbers and data [33]. Relative closeness values and ranks of UAVs are represented in Table 7. UAV 1 with the highest relative closeness value is the best aircraft. The ranking of UAVs is the same as the fuzzy Choquet integral.

Table 7. Fuzzy TOPSIS Results.

UAVs	Relative Closeness Values	Rank
UAV-1	0,581	1
UAV-2	0,549	3
UAV-3	0,567	2

6. CONCLUSIONS

Unmanned aerial vehicles are one of the aircraft that have gained importance, especially in recent years. The fact that these vehicles are used in many operations (meteorological research, reconnaissance surveillance, etc.) and they have many advantages such as flying without the need for a pilot compared to a manned aircraft and low purchase cost made these vehicles attractive. Due to these advantages, many countries and companies have accelerated the production of UAVs. Meeting the need for UAVs is a difficult decision, as there are many alternatives and there are many criteria that affect purchasing.

Since the proposed approach does not require the decision-maker to assign exact values to UAV selection criteria it is very practical. Thanks to this method, the decision-maker can define his/her preferences by using linguistic variables as well as interval range. This advantage eliminates subjective decision errors.

Although the proposed approach provides the decision-maker to define references as linguistic and interval range the computation processes of the method are very complicated. A UAV selection is a multi-criteria decision-making issue that requires multiple criteria. This study shows that the proposed approach provides an excellent tool for the solution as these parameters involve interactions with each other. This study also showed that the fuzzy Choquet integral method can be applied in a vehicle selection problem and it fills a gap in the literature. The current study can be extended by considering multi-objective decision-making techniques such as linear physical programming and goal programming for further research.

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