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A Multi-Criteria Solution Approach for UAV Engine Selection in Terms of Technical Specification

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Abstract
Unmanned Aerial Vehicles (UAVs) are electronic systems that are used extensively in every field today and that develop and change very quickly with technology. UAVs are used extensively in many areas, especially in logistics processes, search and rescue activities, military operations, fight to forest fires, photography, monitoring and inspection of agricultural processes. Furthermore, considering their hobby use, it is understood that UAVs have a large commercial market and a high economic value. UAV systems contain many electronic and mechanical systems and many performance criteria can be found for UAV systems. The main ones of these performances are stabilization and engine power. The most important system affecting these performance criteria is the engine. In this study, engine alternatives available in the market for UAVs with take-off weights of 750 to 800 grams were evaluated in terms of mechanical and physical criteria of engine systems, and as a result, the ideal engine model was determined by Analytic Hierarchy Process (AHP) for maximum stabilization and velocity purposes. The article is the first in the literature in terms of the problem obtained and the application of the AHP method to this problem. Thanks to the study, it is aimed to create a Decision Support System for both UAV manufacturers and UAV users so that they can choose the ideal models in engine selection processes.

1. Introduction

Unmanned Aerial Vehicles are electro-mechanical, autonomous or semi-autonomous devices that do not contain humans and can be controlled by means of remote control, etc. UAVs, which have different take-off weights and dimensions, are divided into three different categories in terms of rotors: fixed, rotary wing and hybrid. In addition, it is possible to group UAVs according to their altitude and range. UAV systems, which were used extensively in military operations in previous years, are now being integrated into many fields and are used intensively for civilian and commercial purposes. Mapping, monitoring, seeding and agricultural spraying processes of agricultural regions are made possible by UAV technologies quickly and easily. Taking instant, detailed and high-altitude images and sharing them in television and digital media is very easy thanks to UAVs. UAV technologies are used extensively in tracking and viewing traffic, creating traffic density maps in city centers and solving these problems. UAV systems are used extensively in fire extinguishing operations in summer and avalanche activities in winter, in the transportation of materials such as water, equipment, etc., as well as in taking snapshots from difficult geographical conditions. Thanks to the use of UAV systems in the tasks of monitoring nuclear, biological, radioactive or chemical processes and tracking leaks arising from them, human life is protected and the right decisions are made. Reconnaissance and surveillance missions for military and security purposes are another area where UAV systems and technologies are used. People use

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UAV systems for photography and hobby purposes, and the number of civilian users is increasing day by day. In recent years, the use of UAVs has increased considerably in the health sector. In particular, UAV systems are used to quickly deliver first aid materials such as blood and medicine to the beneficiaries or hospitals in traffic jams and difficult geographical and climatic conditions. The effective production and design of these systems, which are used extensively, is of great importance.

Drone systems generally consist of 13 different parts: Chassis, Propellers, Motors, Gimbals, Signal Lights, Screws, Camera, GPS (Global Positioning System), Landing Gear, Batteries, Electronic Speed Control Units, Compass and Cables. Each of these sections has a great importance, and "Engines and Propellers" is one of these systems. Thanks to the motor system, the drones convert the motion information coming through the signal into mechanical motion and can move stably in the desired format and orbit in the air. The effective and efficient design of the engine system is of great importance in terms of drone production. Today, there are many companies that design and manufacture motors and propellers for drones in different categories. Selecting the ideal engine system among many alternative brands under various criteria for the relevant drone is difficult and takes a lot of time if any analytical method is used. There are many studies on the design of drone systems in the literature, and in this article, the related problem is solved by using the Analytical Hierarchy Method, one of the most frequently employed Multi-Criteria Decision Making Methods. There is no study in the literature on the application of the AHP method in UAV engine selection. Furthermore, the studies in the literature regarding the applications of Multi-Criteria Decision Making methods and AHP methodology on Unmanned Aerial Vehicles are given below.

Uçar and İşleyen used the AHP method to select the UAVs that will take part in UAV operations with heterogeneous fleets and to prioritize the targets. [1]. Tamer and Uçakcıoğlu determined the ideal investment project for an enterprise operating in the air defense sector by using the AHP and VIKOR method. [2]. Ulukavak and Miman determined the ideal type of UAV that can be used in emergency transportation using the AHP method [3]. Özaslan et al., evaluated single-engine piston airplanes using AHP and TOPSIS methods and determined the ideal one. [4]. Zhao et al., used AHP and Grey Relational Analysis methodologies for UAV recovery system selection [5]. Tuba et al., used Fuzzy Logic and AHP methods for the meteorological forecasting systems of Unmanned Aerial Vehicles by integrating them [6]. Yan et al., evaluated the UAV equipment maintenance quality by using the AHP method [7]. Yıldızbaşı and Gür, developed a decision support system using AHP and TOPSIS methods for the correct and effective use of UAVs after the earthquake disaster [8]. Wang et al., determined the ideal design strategy to be used in the design of power systems of small UAVs with the Local Gray Relational Analysis-Analytic Hierarchy Process (LGRA-AHP) method [9]. HE et al., utilized the AHP method to determine the PID control parameters of the Unmanned Aerial Vehicle [10]. Lai and Whidborne, benefited from the AHP method in solving the return-to-route automation problem in UAVs [11]. Canetta et al., used the AHP method to evaluate potential partners serving in the UAV industry [12].

In addition to these studies, there are many studies in the literature on the engine and propeller efficiency of UAVs. Gur and Rosen proposed a multidisciplinary solution approach to optimize propeller system designs for ultralight aircraft [13]. Gaggero et al. developed a multidisciplinary design optimization to optimize high-speed craft propeller system [14]. Dundar et al. used the Simulation method to determine the ideal designs of multirotor and propeller systems that will maximize the endurance of fixed-wing UAVs [15]. Bayraktar and Güldaş, investigated the efficiency of the thrust and torque systems of the quadrotors using the simulation method [16]. Foeth used the NSGA-II algorithm to optimize the parameters on the propeller geometry [17]. Lee et al. have benefited from genetic algorithm to increase the hovering time of quadcopters [18]. Bacciaglia et al., have developed a solution approach based on Particle Swarm Optimization to design of the pitch propeller [19]. Zhang et al. developed an optimization approach based on multidisciplinary design for a fixed-wing hybrid UAV [20]. Podsedkowski et al., carried out experimental studies on the propeller pitch systems of UAVs for the purpose of propulsion system [21]. Magnussen et al., have optimized the design of the UAV in terms of propeller, engine, battery and other features thanks to the mathematical modeling solution approach [22]. Sinibaldi and Marino examined the propulsion systems of small drones and investigated the difference between their acoustic signature and conventional propellers [23]. Kuantama and Tarca used the CFD method to optimize the thrust system of the quadcopter which has a ducted-propeller [24]. Ahmet et al., used commercial CFD codes to optimize the drone propeller considering the topological purpose [25]. Kapsalis et al., optimized a fixed-wing tactical UAV design using CFD codes [26]. Dahal et al., carried out experimental studies to realize the UAV propeller design under the objective of optimal thrust and used the CFD method to verify the experimental results [27]. ElGhazali and Dol enhaced the propeller design of a multi-rotor UAV by conducting experimental studies in the ANSYS Fluent 16. Program [28]. Andria et al., developed a new drone propeller and compared it with different propeller models for the purpose of thrust [29]. Iannace et al., detected the errors in the drone propeller system using the artificial neural network method [30]. Dumıtrache et al., used the Blade Element Momentum Theory (BEMT) for drone propeller design and evaluated the designed propeller systems in terms of performance characteristics [31]. In addition to the information above, studies related to the subject in the literature are given in Table 1.

Table 1. Studies in the literature on UAV

Author(s)	Year	Problem	Methodology	Index
Rakhade et al.	2021	Agricultural drone selection	AHP and TOPSIS	[32]
Sah et al.	2021	Barriers in the logistics applications of drones	Fuzzy FDM and AHP	[33]
Zhang et al.	2021	The use of drones in emergency situations	AHP, ANP, DEMATEL	[34]
Zhou et al.	2021	Use of UAV in fire fighting	Ant Colony Algorithm and AHP	[35]
Zoltan et al.	2013	Meteorological support system	Fuzzy logic–based analog forecasting method and AHP	[36]
Ardil	2021	Military fighter aircraft selection	PARIS	[37]
Adem et al.	2022	UAV use in the logistics industry and logistics 4.0	AHP	[38]
Moaddab et al.	2020	Monitoring of monitoring gas pipeline with UAV	AHP	[39]
Hsiao and Peng	2020	Multirotor drone appearance selection	F-FCE and F-AHP	[40]
Khan et al.	2021	Drone selection	AHP and TOPSIS	[41]
Wang et al.	2013	UAV power system model	LGRA-AHP	[42]
Müezzinoğlu and Karaköse	2021	Drone control with wearable gloves	Machine learning	[43]
Tanyeri et al.	2022	Drone PID control	Statistical analysis	[44]
Petkovics et al.	2017	UAV Selection	AHP	[45]
Radovanović et al.	2021	UAV Selection	Fuzzy AHP-VIKOR	[46]
Hamurcu and Eren	2022	UAV Selection	AHP and TOPSIS	[47]

There are many parameters and constraints that affect the UAV engine selection. It is difficult and takes a lot of time to determine the ideal one among many engine alternatives, taking into account different purposes and parameters simultaneously, without using analytical methods. There is no study in the literature that evaluates engine selection from an analytical point of view. This article differs from the studies in the literature due to the systematic evaluation of engine selection, the absence of any study on UAV engine selection in the literature, and the use of the AHP method, which is one of the MCDM methods, for the first time in solving the problem. In addition, this article differs from other studies in the literature due to the consideration of velocity and stabilization purposes in engine selection. This paper is structured as follows. Section 2 express, the details of the considered problem are expressed and the used methodology is defined in Section 3. Section 4, the application study is carried out. Finally, in Section 5, general evaluations about the study are expressed.

2. Definition of the Problem

Unmanned Aerial Vehicles basically consist of 12 different components (chassis, propeller, electronic speed control unit, Signal lights, Cables, screws, batteries, GPS, landing gear, Camera, Gimbal, Compass and engines one of the most important components of the UAV, are the mechanical systems that enable the UAV to hover in the air and move in the desired formation by transferring the signals coming from the control and the power it receives from the battery to the propeller. In rotary-wing

UAVs, an engine is needed for each propeller and the thrust varies according to the weight of the UAV. Brushless DC motors are generally used in UAV systems. In addition, battery power varies depending on engine power, more powerful batteries are needed to run more powerful engines. The engine structure also affects the propeller design, and in case of using propeller systems with a larger diameter than the engine can handle, the UAV can move unevenly and the flight time is shortened [48]. There are many criteria to consider when determining the ideal engine type for any UAV. In addition, with the developing technology, there are many alternative engine brands in the market and it is difficult to choose the ideal engine type among the relevant engine criteria without using any analytical method. In this study, alternative engine brands are evaluated under the specified engine selection criteria and the best engine brand is determined by using the AHP method. Looking at the studies in the literature on drones, it has been observed that in general, they are concerned with design and mechanical problems. The brand and model selection for the parts to be used in the drone has been ignored. In this study, the ideal engine selection problem for the drone is discussed. In this context, the technical features of the engine in terms of stabilization and speed were determined and the ideal engine was selected according to these features. As far as is known, there is no study in the literature on determining the ideal engine type using the AHP method for speed and stabilization purposes for drone engines. Thanks to the study, it is aimed to create a decision support system for UAV users, whose numbers reach billions. In this article, 7 different criteria and 15 different alternatives are considered. Information on the criteria is given in Table 2. In the next section, information on the details of the AHP method used in solving the problem is given [4].

Table 2. Information regarding engine criteria

Criteria Name	Criteria Unit	Criteria Detail
Motor KV Value	Kv	It is used for brushless motors. It is the expression coefficient of the revolution that can occur in 1 minute with a voltage. As the motor revolution per voltage decreases, the propeller torque increases and the propeller speed decreases. In this case, the aircraft speed decreases, while the stabilization increases.
Operating Voltage	Volt	It states to the potential energy needed for the operation of electric motors. As the operating voltage of the motor increases, the revolutions per voltage decrease. In this case, while the vehicle speed decreases, the stabilization increases.
Operating Current	Ampere	It expresses the electron current needed in electric motors. As the operating current increases, the motor power increases. Stabilization and speed increase as motor power increases.
Motor RPM	Revolutions per Minute	In electric motors, it refers to the number of revolutions per minute of the motor shaft. Engine speed is directly related to the propeller. As engine speed increases, stabilization and aircraft speed increase.
Motor Torque	Newton metre	In electric motors, it refers to the torque used to rotate the motor shaft. Motor torque is the most effective parameter against disturbances. Stabilization increases as engine torque increases.
Motor Power	Watt	It expresses to the potential of an electric motor to convert electrical energy into mechanical energy. Motor power is related to both motor speed and motor torque. As motor power increases, stabilization and aircraft speed increase.
Motor Weight	Gram	It states to the total weight of the components that make up the motor. Engine weight is the parameter that affects the total take-off weight. Stabilization and speed decrease as take-off weight increases.

3. Solution Methodology

In this paper, in order to gain the importance degree or the weights of alternative UAV engines the AHP which was developed by Thomas L. Saaty in 1977 to solve complex multi criteria decision making problems [49] was utilized. The employed version of the AHP technique in this study is the traditional style, which was developed with 1-9 scale. The logic of the AHP is based on linear algebra, and it compares the parts of the decision-making process pairwise [50]. AHP is a hierarchical representation of a decision-making issue [51]. The superiority of this technique can be explained by the fact that it can compute the weights of both tangible and intangible factors in a decision-making issue [52]. The main steps of the AHP technique are given as follows [53]:

1. Define the decision-making problem and the hierarchy of it
2. Construct the pairwise comparison matrices (PCM) and calculate the consistency ratio of them
3. Calculate the priorities / weights

The following explanations about the AHP methodology are based on Saaty [52]. In the first step, the decision problem is defined in detail. The purpose of the decision problem, the alternatives, the criteria that will affect the decision, and the sub-criteria, if exist, are determined. In the second step, PCM(A) are construct (Eq.1). A comparison scale is utilized in the determination of a_{ij} values in these matrices (see Table 3).

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} \tag{1}$$

Table 3. Importance scale [48].

Importance Degree	Definition
1	Equal
3	Medium importance
5	High importance
7	Very high importance
9	Absolute importance
2,4,6,8	Intermediate values

The values on the diagonal of matrix *A (i.e. i=j)* are equal to 1. Pairwise comparisons are conducted in the upper triangular region. Eq. (2) is utilized to determine the values of the elements in the lower triangle.

$$a_{ji} = 1 / a_{ij} \tag{2}$$

In the third step, the weights of criteria are calculated based on pairwise comparison matrices. This calculation is conducted by determining the column summation of the PCM, dividing each item of the PCM by the corresponding column sum (normalized PCM), and obtaining the priority/weight corresponding to the factor of row averages of the normalized PCM. The mathematical expression of these operations is Eq. (3) and Eq. (4).

$$c_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{3}$$

$$C = \begin{pmatrix} c_{11} & \cdots & c_{1n} \\ \vdots & \ddots & \vdots \\ c_{m1} & \cdots & c_{mn} \end{pmatrix} \tag{4}$$

The *C* matrix represents the normalized PCM. With the row average of this matrix, the *W* vector containing the factor weights is obtained (Eq. (5) and Eq. (6)).

$$w = \begin{pmatrix} w_1 \\ . \\ . \\ . \\ w_n \end{pmatrix} \tag{5}$$

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \tag{6}$$

Determining whether the paired comparisons are consistent is an important step for the AHP method. For calculating a consistency ratio for any pairwise comparison matrix the following steps are applied: Multiplying the column values of the PCM with the weight value corresponding to the relevant factor and adding the row values to create a weighted totals vector, dividing the weighted totals vector by the weights corresponding to the elements and calculating the average of the obtained values (λ_{max}), then calculating the consistency index (*CI*), and calculation of the consistency ratio (*CR*). The weighted sum vector is obtained by Eq. (7).

$$D = \begin{pmatrix} w_1 \\ . \\ . \\ . \\ . \\ w_n \end{pmatrix} x \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ a_{21} & & a_{22} \\ \vdots & \ddots & \vdots \\ \vdots & & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} = \begin{pmatrix} d_1 \\ . \\ . \\ . \\ . \\ d_n \end{pmatrix} \tag{7}$$

Dividing the weighted sums vector by priorities are expressed by Eq. (8) and Eq. (9).

$$E = \begin{pmatrix} e_1 \\ . \\ . \\ . \\ . \\ e_n \end{pmatrix} \tag{8}$$

$$e_i = \frac{d_i}{w_i} \tag{9}$$

λ_{max} is calculated by utilizing Eq. (10):

$$\lambda_{\max} = \frac{\sum_{i=1}^{n} E_i}{n} \tag{10}$$

Consistency index is computed with the help of Eq. (11):

$$CI = \frac{\lambda - n}{n-1} \tag{11}$$

The consistency ratio is calculated with Eq. (12):

$$CR = \frac{CI}{RI} \tag{12}$$

The RI expression in Eq.12 expresses a standard value, and the values according to the number of factors are shown in Table 4.

Table 4. Random index (*RI*)

Number of element	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.48

If the calculated CR value is less than 0.1, the PCM performed is considered consistent. Otherwise, the PCM should be rearranged [54].

4. Application

In this paper, due to its less complex calculation steps but having powerful solution potential, The AHP technique was utilized in analyzing UAV's engine specifications. The hierarchical decision tree developed for the problem is shown in Figure 1.

In the first step of the application, the weights of criteria were calculated. Table 5 shows the pairwise comparison matrix of the selection criteria. All presented matrices are the compromised matrices by the expert team.

Table 6 shows the calculated weights of criteria by applying Eq. (2)- Eq. (6). The consistency ratio of this PCM was computed as 0.097 with the help of Eq. (7)- Eq. (12), because this value is lower than 0.1, this PCM is consistent.

Table 5. Pairwise comparisons of the criteria

Criteria	**Motor KV Value**	**Operating Voltage**	**Operating Current**	**Motor RPM**	**Motor Torque**	**Motor Power**	**Motor Weight**
Motor KV Value	1	3	5	3	4	5	9
Operating Voltage	-	1	3	1/3	5	3	3
Operating Current	-	-	1	1	3	2	3
Motor RPM	-	-	-	1	4	3	4
Motor Torque	-	-	-	-	1	1/3	1/3
Motor Power	-	-	-	-	-	1	4
Motor Weight	-	-	-	-	-	-	1

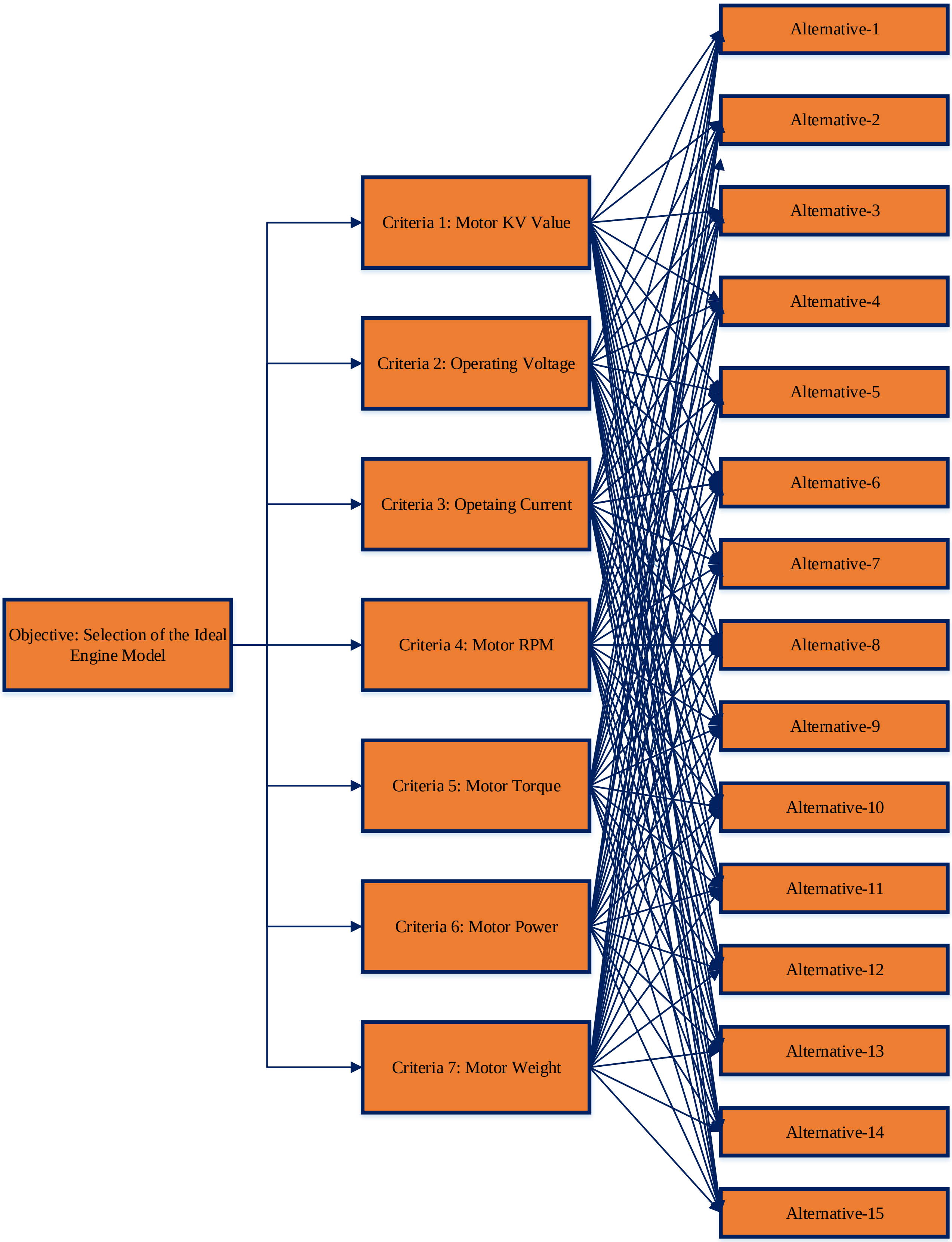

Figure 1. The hierarchical representation developed for the decision problem

Table 6. The weights of the criteria

Criteria	Criteria weights
Motor KV Value	0,371
Operating Voltage	0,161
Operating Current	0,109
Motor RPM	0,186
Motor Torque	0,040
Motor Power	0,084
Motor Weight	0,049

CR=0.097

First of all, on the basis of each criterion, the alternatives were compared in pairs and their weight values were obtained according to both velocity and stabilization. For each aim, 7 comparison matrix (15*15 alternatives) were constructed. The consistency ratios of all evaluation matrices were checked and they were specified as consistent. Table 7 shows the results of the pairwise comparisons of alternatives with respect to each criterion according to the aim of velocity. This table is obtained after a pairwise comparison of 15 alternatives on the basis of each criterion and calculations with AHP.

Table 7. The results of the pairwise comparisons of alternatives with respect to each criterion according to the aim of velocity

Alt.	C1	C2	C3	C4	C5	C6	C7
A1	0.094	0.108	0.036	0.024	0.031	0.041	0.019
A2	0.094	0.063	0.055	0.059	0.041	0.062	0.027
A3	0.094	0.112	0.120	0.024	0.021	0.020	0.102
A4	0.094	0.057	0.019	0.059	0.102	0.100	0.019
A5	0.139	0.057	0.018	0.089	0.067	0.100	0.043
A6	0.029	0.039	0.044	0.038	0.067	0.062	0.043
A7	0.035	0.040	0.040	0.038	0.102	0.072	0.069
A8	0.206	0.057	0.126	0.225	0.011	0.014	0.249
A9	0.063	0.061	0.019	0.038	0.149	0.100	0.013
A10	0.014	0.197	0.267	0.012	0.012	0.011	0.145
A11	0.043	0.022	0.050	0.169	0.206	0.209	0.043
A12	0.014	0.022	0.036	0.125	0.067	0.100	0.043
A13	0.043	0.063	0.035	0.059	0.067	0.059	0.043
A14	0.019	0.068	0.054	0.016	0.030	0.029	0.043
A15	0.019	0.034	0.080	0.024	0.027	0.020	0.100

Table 8 shows the calculated values of alternatives with respect to the aim of velocity. The values in Table 8 are obtained by multiplying the weights of the criteria with the weight of the alternative on the basis of the relevant criteria (see Table 7).
To illustrate, the first row of Table 8 is computed as follows:

$$0.094*0{,}371 \approx 0.0350$$
$$0.108*0{,}161\approx0.0173$$
$$0.036*0{,}109\approx0.0039$$
$$0.024*0{,}186\approx0.0045$$
$$0.031*0{,}040\approx0.0012$$
$$0.041*0{,}084\approx0.0034$$
$$0.019*0{,}049\approx0.0009$$

The total column shows the summation of these values, thus,
$0.0350+0.0173+0.0039+0.0045+0.0012+0.0034+0.0009\approx0.0663$

Table 8. The calculated values of alternatives with respect to the aim of velocity.

Alternatives	C1	C2	C3	C4	C5	C6	C7	Total
A1	0.0350	0.0173	0.0039	0.0045	0.0012	0.0034	0.0009	0.0663
A2	0.0350	0.0102	0.0061	0.0110	0.0016	0.0052	0.0013	0.0705
A3	0.0350	0.0180	0.0131	0.0045	0.0008	0.0017	0.0051	0.0782
A4	0.0350	0.0091	0.0021	0.0110	0.0041	0.0084	0.0009	0.0706
A5	0.0515	0.0092	0.0020	0.0165	0.0026	0.0084	0.0021	0.0922
A6	0.0107	0.0063	0.0049	0.0070	0.0026	0.0052	0.0021	0.0388
A7	0.0129	0.0064	0.0044	0.0070	0.0041	0.0060	0.0034	0.0443
A8	0.0766	0.0092	0.0137	0.0418	0.0005	0.0012	0.0123	0.1553
A9	0.0235	0.0098	0.0021	0.0070	0.0059	0.0084	0.0006	0.0573
A10	0.0050	0.0317	0.0292	0.0022	0.0005	0.0009	0.0072	0.0768
A11	0.0159	0.0035	0.0054	0.0314	0.0082	0.0175	0.0021	0.0841
A12	0.0050	0.0036	0.0040	0.0231	0.0026	0.0084	0.0021	0.0488
A13	0.0159	0.0102	0.0038	0.0110	0.0026	0.0050	0.0021	0.0506
A14	0.0070	0.0110	0.0059	0.0030	0.0012	0.0024	0.0021	0.0326
A15	0.0072	0.0055	0.0088	0.0045	0.0011	0.0017	0.0050	0.0336

Figure 2 shows the priority values of alternatives for velocity aim. As a result, it was determined that the most suitable engine models for "velocity aim" are A8 and A11, respectively. In addition, it has been determined that the engines with the lowest importance were A14-A15 and A6, respectively

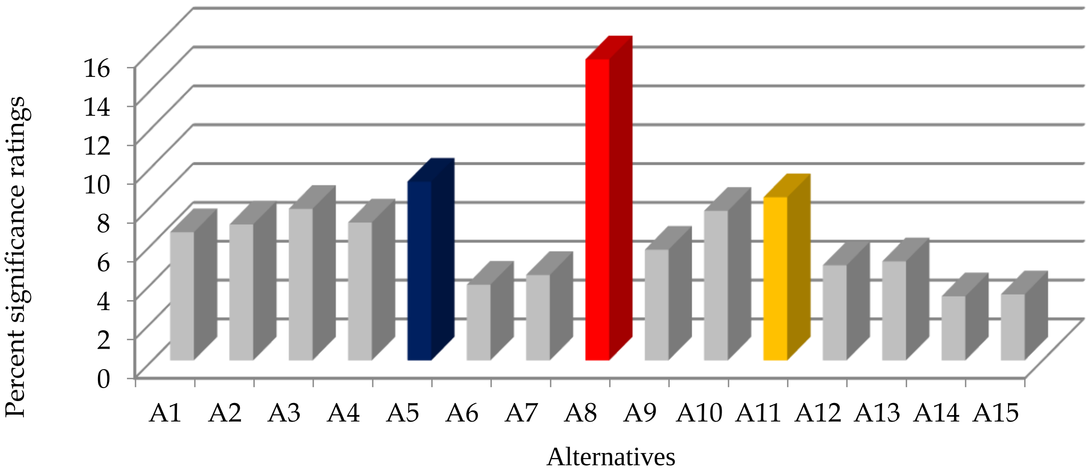

Figure 2. Priority values of alternatives for velocity aim

For stabilization aim, 7 comparison matrix (15*15) were constructed. The consistency ratios of all evaluation matrices were checked and they were specified as consistent. Tale 9 is obtained after a pairwise comparison of 15 alternatives on the basis of each criterion and calculations with AHP.

Table 9. The results of the pairwise comparisons of alternatives with respect to each criterion according to the aim of stabilization.

Alt	C1	C2	C3	C4	C5	C6	C7
A1	0.095	0.131	0.042	0.024	0.030	0.041	0.019
A2	0.095	0.055	0.063	0.059	0.041	0.063	0.027
A3	0.095	0.131	0.132	0.024	0.020	0.020	0.102
A4	0.095	0.055	0.020	0.059	0.102	0.101	0.019
A5	0.139	0.055	0.020	0.089	0.067	0.101	0.043
A6	0.029	0.034	0.042	0.038	0.067	0.063	0.043
A7	0.029	0.034	0.040	0.038	0.102	0.063	0.069
A8	0.207	0.055	0.125	0.225	0.012	0.015	0.249
A9	0.064	0.055	0.020	0.038	0.149	0.101	0.013
A10	0.014	0.237	0.221	0.012	0.012	0.011	0.145
A11	0.043	0.012	0.061	0.169	0.206	0.210	0.043
A12	0.014	0.012	0.035	0.125	0.067	0.101	0.043
A13	0.043	0.055	0.037	0.059	0.067	0.063	0.043
A14	0.020	0.055	0.057	0.016	0.030	0.029	0.043
A15	0.020	0.023	0.085	0.024	0.030	0.020	0.100

Table 9 show the results of the pairwise comparisons of alternatives with respect to each criterion according to the aim of stabilization. Same calculation steps to velocity purpose were repeated for the aim of the stabilization and the results were summarized Table 10.

Table 10 presents the calculated values of alternatives with respect to the aim of stabilization. Table 9 are obtained by multiplying the weights of the criteria (see Table 6) with the weight of the alternative on the basis of the relevant criteria (see Table 9).

As seen in Figure 3, it can be concluded that A8, A5 and A11 engine types are respectively the best engine for stabilization purpose as well as for speed. In addition, it is expressed in the results that the A14, A15 and A16 alternatives are the least important engine models.

Based on the results of two analyses, it has been determined that the ideal engine type for the Unmanned Aerial Vehicle between 750 and 800 grams is A8 and a decision support system has been created for decision makers.

Table 10. The calculated values of alternatives with respect to the aim of stabilization

Alternatives	C1	C2	C3	C4	C5	C6	C7	Total
A1	0.035	0.021	0.005	0.004	0.001	0.003	0.001	0.071
A2	0.035	0.009	0.007	0.011	0.002	0.005	0.001	0.070
A3	0.035	0.021	0.014	0.004	0.001	0.002	0.005	0.083
A4	0.035	0.009	0.002	0.011	0.004	0.008	0.001	0.071
A5	0.052	0.009	0.002	0.016	0.003	0.008	0.002	0.092
A6	0.011	0.005	0.005	0.007	0.003	0.005	0.002	0.038
A7	0.011	0.005	0.004	0.007	0.004	0.005	0.003	0.040
A8	0.077	0.009	0.014	0.042	0.000	0.001	0.012	0.155
A9	0.024	0.009	0.002	0.007	0.006	0.008	0.001	0.057
A10	0.005	0.038	0.024	0.002	0.000	0.001	0.007	0.078
A11	0.016	0.002	0.007	0.031	0.008	0.018	0.002	0.084
A12	0.005	0.002	0.004	0.023	0.003	0.008	0.002	0.047
A13	0.016	0.009	0.004	0.011	0.003	0.005	0.002	0.050
A14	0.007	0.009	0.006	0.003	0.001	0.002	0.002	0.031
A15	0.007	0.004	0.009	0.004	0.001	0.002	0.005	0.033

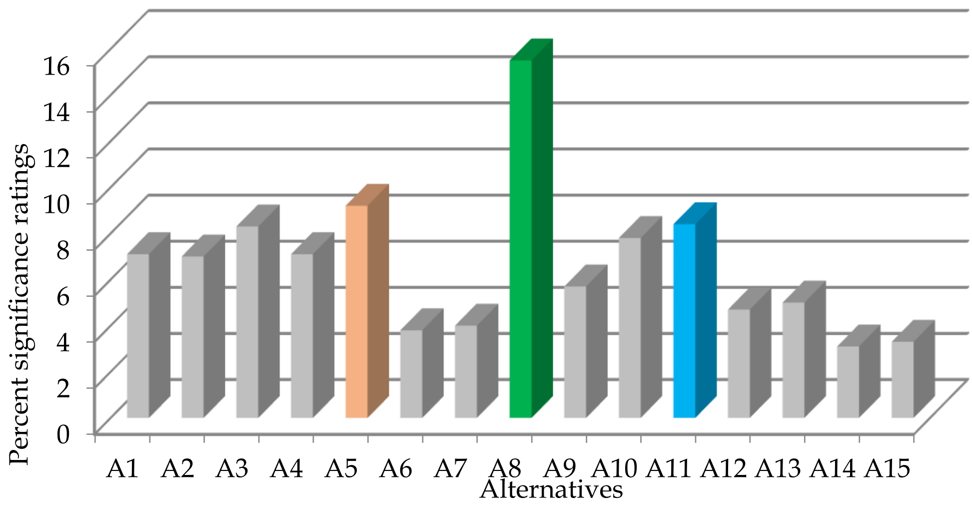

Figure 3. Priority values of alternatives for stabilization purpose.

5. Conclusion

Thanks to the developing technology, the production and user of UAVs for civil and military purposes are increasing rapidly and these technologies are used intensively in many areas, especially in traffic, health, logistics, security, transportation, agriculture, photography and hobby. UAV technologies consist of many different systems and it is of great importance that these components are produced effectively, efficiently and safely. In addition, there are many UAV manufacturers that produce components with different quality and features for any UAV type, and choosing the ideal brand and model for the UAV is of great importance in terms of UAV performance. In this study, the ideal engine type engine was determined by considering 7 different criteria among 15 different alternative engine types for drones with take-off weights of 750 to 800 grams. "Motor KV Value", "Operating Voltage", "Operating Current", "Motor Speed", "Motor Torque", "Motor Power" and "Motor Weight" criteria have been taken into account in the selection of the engine, thus allowing the drone to achieve maximum stabilization and power. The ideal engine brand has been determined. The study is the first in the literature due to the problem addressed and the use of the AHP method in this problem. As a result of the analysis study, it has been determined that the most important criterion in engine selection is the "Motor KV" value, and the ideal engine brand is "A8".

The study is a decision support system for UAV manufacturers and users. With the proposed mechanism, UAV users will be able to evaluate the suitable brand among themselves among performance and different criteria and make the right choices. Furthermore, UAV manufacturers will be able to identify the ideal supplier among their own suppliers using the determined solution approach. Considering that there are millions of UAV users in the world, the benefit of the proposed approach can be better understood.

In future studies, it is predicted that researchers can increase the number of criteria and alternatives and obtain more effective and comprehensive solutions by using different solution methodologies. Besides, it is anticipated that highly efficient and flexible decision support systems can be developed by supporting a large database, a user-interactive interface and artificial intelligence technologies of the proposed approach.

Contributions of the Authors

Each author contributed equally to the article.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics

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