ANKARA SCIENCE UNIVERSITY, RESEARCHER
Vol. 5, No. 1, July 2025
e-ISSN: 2717-9494
Research Article/Araştırma Makalesi

A Prioritization Analysis for UAVs in Disaster Response

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Received: 15 October 2024; Accepted: 10 July 2025

Reference/Atıf: M. Erdoğan ve A. Koşak, "A Prioritization Analysis for UAVs in Disaster Response", Researcher, c. 05, sy. 01, ss. 1–16.

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Abstract

Many natural disasters happen in the world every year. Disasters make it difficult for people to reach their basic needs and can cause unpredictable loss of life. For this reason, emergency response and resource management are of critical importance in case of disaster. Since there is serious damage to the transportation infrastructure after the disaster, the roads, bridges and railway lines become unusable, making it difficult for the teams and relief materials to reach the disaster area by traditional methods, creating danger and increasing the loss of life. In cases where transportation is not possible, the fact that unmanned aerial vehicles (UAVs) increase accessibility to the disaster area creates a serious advantage in disaster times. UAVs reduce the possible environmental effects causing delays in the event of a disaster compared to transportation by traditional methods, can take part in dangerous conditions, can provide medicines and food supply, and can provide fast and safe transportation of needs to disaster victims. In this study, UAVs that can provide the medicine and food needed after a disaster are prioritized by using a multi-criteria decision-making (MCDM) approach with six main criteria and twenty-one sub-criteria determined. Seven UAV alternatives have been analyzed to use in disaster times primarily. Analytical Hierarchy Process (AHP) method has been adopted to weigh the criteria and Average Distance to Solution (EDAS) method has been used for the evaluation and prioritization of alternatives. This study is the first to use the EDAS method for the supply of medicine and food in disaster situations. In order to compare the results of the study, Complex Proportional Assessment (COPRAS) and Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) multi-criteria decision-making methods have been also utilized. Sensitivity analyses have been performed to determine the effect of criteria weights on the ranking of alternatives. The reliability and robustness of the results have been investigated through comparison and sensitivity analyses.

Keywords: disaster response, humanitarian logistics, multi-criteria decision making, unmanned aerial vehicles

1. Introduction

Disasters often cause people to leave their homes or have difficulty meeting their basic needs. With the prioritization of unmanned aerial vehicles (UAVs) for the supply of food and medicine, disaster victims will be able to reach their basic nutritional and health needs. The initial few hours after a disaster, when victims have the best chance of surviving, are referred to as the crucial phase. All human resources that are available after a disaster must be directed toward the search and rescue effort. Furthermore, coordinating rescue efforts and expeditiously evaluating the disaster's impact are critical components of response activities. [1]. In case of disaster, food and medicine supply has a critical role in protecting the lives of disaster victims, ensuring their health, and contributing to the rapid recovery of society. Providing this supply regularly, effectively and quickly is considered a vital element in post-disaster response. Health risks such as water pollution, food insecurity and hygiene problems may arise during disasters. UAVs play a critical role in drug supply to prevent the spread of diseases and intervene in existing health problems, and those who are less affected by environmental conditions can deliver drugs and other needs quickly. Because it is important to quickly access the disaster area and meet basic needs, UAVs provide support for medicine and food supplies, emergency aid and rescue operations. In this way, food and medicine supply will be provided in the fastest, safest and most efficient way in case of disaster [2]. Even if damaged and blocked roads pose obstacles in weather and land conditions, it enables unmanned aerial vehicles to quickly reach the disaster area and provide emergency food supply. This paper aimes to ensure the delivery of food and medicine in cases of emergency or disaster and to support emergency aid operations. UAVs that can be used immediately after the disaster have been identified and a multi-criteria analysis has been proposed as to which of them should be used first. With the proposed UAV, it will be possible to complete its task quickly in food and medicine supply by being less affected by environmental conditions. This type of prioritization analysis is intended to evaluate the advantages and potential challenges of using UAVs in disaster situations. This will provide disaster response teams, governments and aid agencies with the ability to act more effectively and quickly. The main purpose of this analysis is to ensure the effective use of UAVs for food and medicine supply in disaster situations. With this evaluation, the effectiveness and durability of UAV models in ensuring the supply of food and medicine in case of disaster is analyzed with the criteria determined via experts and literature review. The fact that there are multiple alternatives and many evaluation criteria in the evaluation process makes it reasonable to conduct this analysis using MCDM approaches. For this purpose, firstly, the evaluation criteria were weighted with AHP, which is one of the most frequently used and reliable MCDM approaches, and then the UAV model recommended to be used as a priority among the UAV alternatives identified using the EDAS method was determined. In order to test the reliability and robustness of the study, comparative and sensitivity analyses were performed, and the results obtained under different scenarios were compared with the results obtained in the current analysis. In the following sections, the literature survey conducted for the study, the proposed hybrid methodology and the comparison analysis and sensitivity analysis are included

2. Literature Review

There are some studies in the literature in which UAVs are evaluated with MCDM methods for use in disaster situations. While analyzing these studies, a large number of research containing the keywords "disaster response", "multi-criteria decision making", "humanitarian logistics", "medicine and aid supply" and "unmanned aerial vehicle" were examined. However, a limited number of studies conducted for the purpose adopted in this paper were found. The studies are summarized as follows in Table 1 in terms of methods used, purpose, year and countries.

Table 1. Literature Research Results

	Author(s)	Year	Aim	Adopted Method(s)	Country
1	Gürbüz et al. [3]	2023	Answering the questions of how, where, in which way, with which species and what type of pesticides for farmers in agriculture in Kırıkkale Province	AHP, TOPSIS, (PROMETHEE), (VIKOR)	Turkey
2	Kara et al. [4]	2023	Making the optimum choice among firefighter drones produced to transport liquids to intervene in fires	AHP and COPRAS	Turkey
3	Ecer et al. [5]	2023	Proposal for an integrated group decision-making framework to identify the best agricultural UAV	q-ROFNs, (LOPCOW), VIKOR	Turkey
4	Garg et al. [6]	2023	Developing sustainable drone delivery solutions	Systematic Literature Review (SLR)	USA
5	Silva et al. [7]	2023	Propose a model that can help decision-makers choose the most appropriate last-mile solution for historical centers	AHP and TOPSIS	Portugal
6	Banik et al. [8]	2023	Choosing the most suitable drone in different scenarios related to medical supply distribution	Graph Theory and Matrix Approximation (GTMA)	USA
7	Tesic et al. [9]	2023	Surveying flooded areas during floods and providing necessary supplies, food and water	Multi-Attribute Boundary Approach Area Comparison (DIBR-Rough Mabac)	Serbia
8	Hossain et al. [10]	2022	Estimating the overall performance of drone technology through four main criteria (factors)	Bayesian Network (BN) approach, Sensitivity Analysis	USA

9	Zahir H. et al. [11]	2022	Strategic framework proposal for optimizing drone capabilities in cities' disaster response	Participatory Action Research (PAR) Approach	Malaysia
10	Dukic et al.	2022	Solving the problem of more efficient and economical training of combat crews on short-range air defense systems	AHP and TOPSIS	Serbia
11	Aktas and Kabak [12]	2022	Proposing a model to determine the most suitable drone alternative	Pythagorean Fuzzy Weighted Aggregate Total Product Evaluation	Turkey
12	Kara et al. [13]	2022	Choosing a drone with similar features produced for material transportation	AHP, TOPSIS and PROMETHEE	Turkey
13	Özaslan et al.	2021	It was determined that there are no studies on the selection of piston single-engine aircraft in individual purchasing in Turkey.	AHP and TOPSIS	Turkey
14	Rejeb, et al. [14]	2021	Analyzing the potential applications of drones in the humanitarian field and structuring research on the subject	Humanitarian Logistics (HL) Research	USA
15	Sohaib Khan et al. [15]	2021	Selection of the highest-order drone by applying the TOPSIS method to the drones on the market at the desired cost	AHP and TOPSIS	Pakistan
16	Fu et al. [16]	2021	Examining the opinions of experts at the consultation stage before enacting a law on civilian UAVs	AHP and Triple Helix Model (THM)	Taiwan
17	Ergun et al. [17]	2021	Development of a game theoretical model for emergency logistics planning	Cooperative Game Theory	Turkey
18	Zhang et al.	2021	Proposing a customized model to identify the top three benefits of drones at both the personal and community level	Fuzzy Analytical Network Process (ANP), Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL)	USA
19	Nur et al. [18]	2020	Comparing a range of existing last-mile delivery drones suggests an extensive list of criteria.	TOPSIS and AHP	USA
20	Glantz et al. [19]	2020	How UAV capabilities are used in disaster management, their current use in disaster management	Examination of MCDM Methods	USA
21	Slavika Dožić [20]	2019	It is to identify and classify the problems solved using the multi-criteria decision-making method in the aviation industry.	Examination of MCDM Methods	Serbia
22	Değirmen et al. [1]	2018	Route planning of unmanned aerial vehicles to be used in disaster areas	Clustering and Mathematical Programming	Turkey
23	Özdemir and Baslıgil [21]	2016	Examining the purchase of aircraft from a Turkish airline using fuzzy numbers	FAHP, FANP, Choquet Integral	Turkey

This study addressed the MCDM problem of prioritizing unmanned aerial vehicles for the use of emergency response teams. When we look at Figure 1, which was prepared based on the studies classified by country in Table 1, Turkey is one of the countries with the highest rate, with 39%, among the countries where studies on the subject have been conducted. After Türkiye, the USA is among the countries where the most studies are observed, with a rate of 31%. In the following order, Serbia with 13%, Portugal with 5%, Pakistan, Taiwan and Malaysia with 4% come next. Our country carries out many studies for the disaster situations that have been experienced and may be experienced, and with the intensity of studies for disaster situations, it is a pioneer for the studies in other countries.

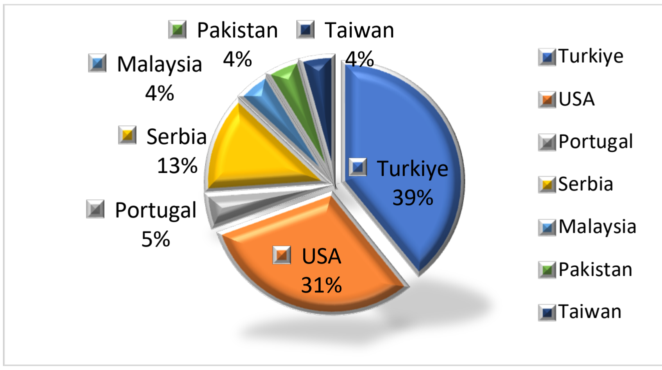

Figure 1. Studies according to their country

MCDM methods are frequently preferred to prioritize unmanned aerial vehicles for use in medicine and food supply in disaster situations. The most preferred methods are AHP, TOPSIS and PROMETHEE respectively. The distributions of these methods according to Table 1 are as in Figure 2. The AHP approach has been seen as the most frequently used MCDM method for UAV-related studies.

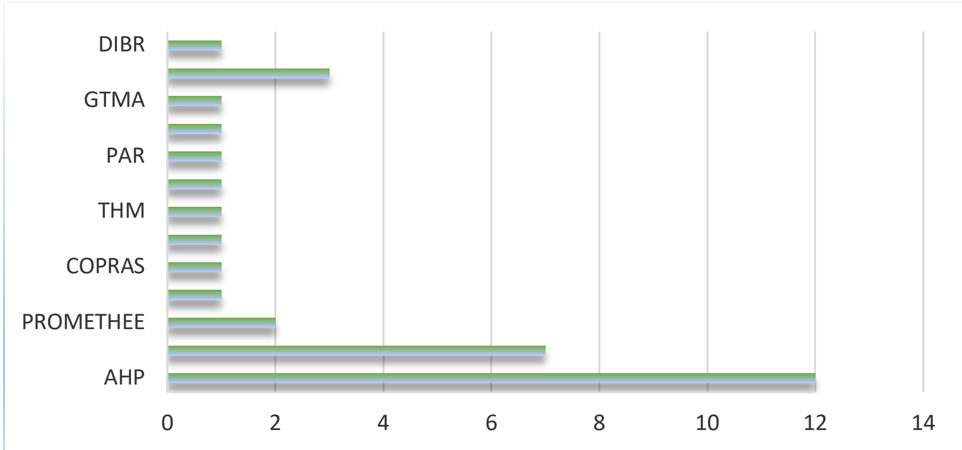

Figure 2. Studies according to their adopted methodology

3. Materials and Methods

In this study, a prioritization analysis has been conducted for the use of UAVs in food and medicine supply in case of post-disaster. Since there are multiple criteria and alternatives in the evaluation process, MCDM methods were adopted for the decision-making process. A hybrid AHP-EDAS MCDM methodology has been used in the study. The evaluation criteria have been weighted with the AHP method, and then the alternatives have been ranked with the EDAS method. With sensitivity analysis, the importance of criterion weights in ranking with different scenarios has been examined; comparative analysis has been carried out with TOPSIS and COPRAS methods and the results have been compared with the rankings obtained as a result of the EDAS method. The flowchart of the paper is shown in Figure 3.

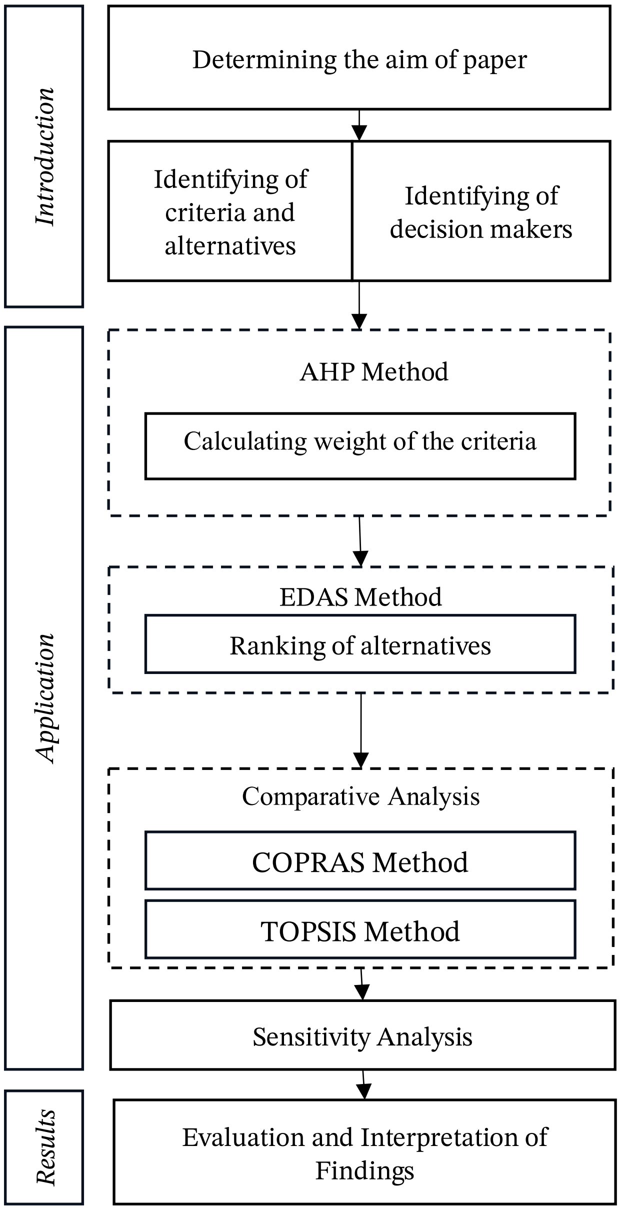

Figure 3. Flow chart of the proposed methodology

3.1 AHP Method

The AHP technique is a mathematical strategy that takes into account all priorities while making a decision. The most basic form employed in the AHP technique to structure a decision problem is a three-level hierarchy: the top-level decision aim, followed by a second level of criteria against which alternatives would be evaluated at the third level. The factors influencing the decision are ordered gradually. The structure's objective is to make it feasible to determine the importance of components at a specific level, based on some or all of the elements at the preceding level [22]. The scale to compare the elements to each other is used in the AHP method shown in Table 2.

Table 2. Linguistic Variables and Equivalents

Numerical Value	Definition	Explanation
1	Equally important	Two options are equally important
3	Moderately important	Moderately preferred one criterion over another
5	Strongly important	Experience and judgment have favored one criterion over another
7	Very strongly important	One criterion is considered superior to the other
9	Extremely important	Extremely more important and preferred
2,4,6,8	Intermediate values	It is used when compromise is necessary

The steps of the AHP method is given in the following [23]–[27];

Step 1: The decision problem is transformed into a hierarchical structure and a comparison matrix is created to show how the criteria are compared to each other as in Eq. (1). While creating the comparison matrix, experts can utilize the linguistic variables in Table 2.

$$B = [b]_{n\,x\,n} \tag{1}$$

Step 2: The consistency of each comparison matrix is checked. If the Consistency Ratio (CR) is less than 0.1, the matrix is considered consistent; otherwise, experts should evaluate the criteria again. Eq. (2) shows the Consistency Index (CI). Eq. (3) shows how the consistency ratio is calculated.

$$CI = \frac{\lambda_{max} - n}{(n-1)} \tag{2}$$

$$CR = \frac{\mathrm{CI}}{RI} \tag{3}$$

*R*I in Eq. (3) shows the randomness index. This value varies depending on the number of criteria. Table 3 gives the RI values according to the number of elements used in the problem.

Table 3. Randomness Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Step 3: The comparison matrix is normalized with Eq. (4). Then, the weight of each criterion is calculated with Eq. (5).

$$b'_{ij} = \frac{b_{ij}}{\sum_{i=1}^{n} b_{ij}} \tag{4}$$

$$w_j = \frac{\sum_{i=1}^{n} b_{ij}^{'}}{\mathrm{n}} \tag{5}$$

3.2 EDAS Method

EDAS method, which can be translated into Turkish as "Evaluation Based on Average Solution Distance", is a new decision-making approach developed by Ghorabaee et al. [28] for the solution of MCDM problems. EDAS method compared with many MCDM methods, for its validity, and was successfully applied in solving many problems [29]. The EDAS method consists of 6 steps shown below [28]:

Step 1: The decision matrix (X) is constructed as shown below by Eq. (6). X_{ij} shows the performance value of ith alternative on jth criterion.

$$X = \left[X_{ij}\right]_{n\times m} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1m} \\ X_{21} & X_{22} & \cdots & X_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ X_{n1} & X_{n2} & \cdots & X_{nm} \end{bmatrix} \quad (6)$$

Step 2: Calculate the average solution according to all criteria, as in

$$AV = [AVj]1xm \quad (7)$$

AV_j represents the average of the criterion and is determined with Eq. (8).

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{n} \quad (8)$$

Step 3: Positive distance from the mean (PDA) and negative distance from the mean (NDA) matrices are defined according to the criterion type (benefit and cost) as follows.

$$PDA = \left[PDA_{ij}\right]_{n\times m} \quad (9)$$

$$NDA = \left[NDA_{ij}\right]_{n\times m} \quad (10)$$

If the criterion is benefit-based, Eq.s (11) and (12) are adopted.

$$PDA_{ij} = \frac{max\left(0, \left(X_{ij} - AV_j\right)\right)}{AV_j} \quad (11)$$

$$NDA_{ij} = \frac{max\left(0, \left(AV_j - X_{ij}\right)\right)}{AV_j} \quad (12)$$

If the criterion is cost-based, Eq. (13) and (14) are adopted.

$$PDA_{ij} = \frac{max\left(0, \left(AV_j - X_{ij}\right)\right)}{AV_j} \quad (13)$$

$$NDA_{ij} = NDA_{ij} = \frac{max\left(0, \left(X_{ij} - AV_j\right)\right)}{AV_j} \quad (14)$$

where PDA_{ij} and NDA_{ij} show the positive and negative distance of i th alternative from the average solution in terms of jth criterion, respectively.

Step 4: SPi and SNi values are found with the help of the following equations.

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \tag{15}$$

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \tag{16}$$

Step 5: Normalization procedure for SPi and SNi values of all alternatives is conducted with the help of the following equations.

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \tag{17}$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \tag{18}$$

Step 6. The appraisal score (AS) of each of the alternatives is calculated.

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \tag{19}$$

ASi in equation (2.3.14) must satisfy the equality $0 \leq ASi \leq 1$.
Step 7. Sort the alternatives according to the evaluation score (AS) results. The alternative with the highest score is considered the best alternative among the candidates.

4. Real Case Application

In this paper, seven UAVs we identified for use in medicine and food supply in case of disaster have been evaluated and prioritized. In order to evaluate the alternatives via the evaluations of the decision makers, six main and twenty-one sub-criteria have been determined as a result of the literature search. The main criteria for this study have been determined as "social", "environmental", "economic" and "technological" and sub-criteria have been also specified in the same way and placed under the appropriate main criteria. During the determination of alternatives, seven alternative UAVs produced for use in medicine and food supply in case of disaster have been considered. Sancak and Jackal-M used in the Kahramanmaraş earthquake; Matternet and Zipline's Zip, used to transport medical supplies during the Covid-19 outbreak; In last mile transportation, Flytrex, Wingcopter 198 and Foxtech Gaia unmanned aerial vehicles are nationally and internationally purchasable, easy to use and preferred tools for combating disasters. The determined drones are taken into account as an alternative by using them for hours under disaster conditions, shaping them according to the needs and considering the capabilities that can withstand difficult conditions. In addition, attention has been paid to the fact that the selected alternatives are physically and cognitively capable and have gained experience. After identifying the seven alternatives that produce drones for use in medicine and food supply in disaster situations, the decision hierarchy has been established. The criteria are determined via the literature review [3]–[5], [7], [8], [10], [14] . The hierarchy created for this paper is shown in Figure 4.

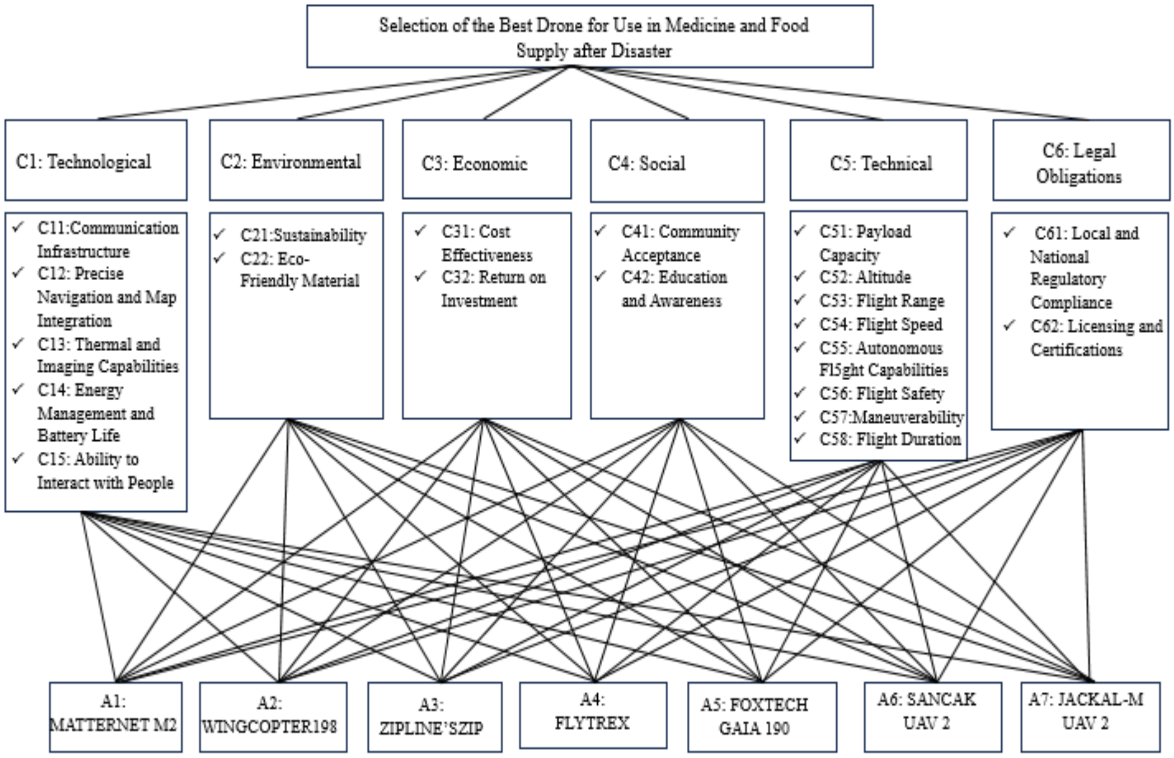

Figure 4. Hierarchical Representation of the Criteria, Sub-criteria and Alternatives

Criteria weights have been calculated using the data obtained from the evaluation of experts. Afterward, the criteria-alternative evaluations obtained by experts are quantified and the ranking of the alternative has been determined using the EDAS method. The results also compare with COPRAS and TOPSIS methods and sensitivity analysis in different scenarios have been conducted. A hierarchical structure has been created by determining criteria and alternatives in line with the selection of drones for use in medicine and food supply. The criteria determined for this decision problem have been evaluated by three experts according to their level of importance. The qualifications of the experts in this problem are presented in Table 4.

Table 4. Information about Experts

Experts	Experience	Job
E1	2023 Teknofest Combat UAV Competition/Composite UAV Production 2022-23 Teknofest Rocket Competition Finalist/ Rocket Production	Member of Düzce University Aviation and Space Technologies Community/Mechanical Engineer
E2	Composite Defense Industry UAV Design and Production	Member of Düzce University Aviation and Space Technologies Community/Mechanical Engineer
E3	2023 Composite UAV Design and Analysis/Ansys Analysis and Solidwork	Düzce University Career Community Chairman of the Board/Mechanical Engineer

For calculating the criteria weights, experts have first evaluated the main criteria to their degree of importance. Afterwards, the geometric mean of the expert evaluations was calculated for each main criterion. Table 5 shows the results of the aggregated evaluation of the main criteria comparison.

Table 5. Aggregated values of expert evaluations for main criteria weighting

	C1	C2	C3	C4	C5	C6
C1	1,000	0,382	0,315	0,369	2,000	3,557
C2	2,621	1,000	1,442	0,500	2,520	4,932
C3	3,175	0,694	1,000	0,550	3,557	4,718
C4	2,714	2,000	1,817	1,000	3,915	5,518
C5	0,281	0,203	0,212	0,181	1,000	0,397
C6	0,500	0,397	0,281	0,255	2,520	1,000

Similarly, for the sub-criteria sets of each main criterion, aggregated evaluations for expert opinions have been calculated with the geometric mean function. Meanwhile, all these pairwise comparison matrices have been checked for consistency. As a result of the consistency analysis, the consistency ratios of all pairwise comparison matrices have been found to be less than 0.1 and the weight calculation stages have been initiated. The consistency ratios calculated for each pairwise comparison matrix are presented in Table 6.

Table 6. Consistency Indexes for Pairwise Comparison Matrices

Comparison Matrix	Consistency Ratio
C1	0,0448
C2	0,0000
C3	0,0000
C4	0,0000
C5	0,0640
C6	0,0000

By applying the AHP steps presented in Section 3.1, the weights of the main criteria and sub-criteria were calculated. These weights are shown in Table 7.

Table 7. Weights of criteria

Main Criteria	Main Criteria Weight	Sub-Criteria	Local Weights	Global Weights
C1	0.1132	C11	0.4950	0.0561
		C12	0.2410	0.0272
		C13	0.1320	0.0150
		C14	0.0870	0.0099
		C15	0.0440	0.0050
C2	0.2230	C21	0.7565	0.1687
		C22	0.2435	0.0543
C3	0.2208	C31	0.8208	0.1812
		C32	0.1792	0.0396
C4	0.3235	C41	0.7965	0.2577
		C42	0.2035	0.0658
C5	0.0777	C51	0.2730	0.0212
		C52	0.2280	0.0177
		C53	0.1590	0.0123
		C54	0.1310	0.0102
		C55	0.0810	0.0063

		C56	0.0570	0.0045
		C57	0.0410	0.0032
		C58	0.0300	0.0024
C6	0.0418	C61	0.8445	0.0353
		C62	0.1555	0.0065

As a result of the multi-criteria analysis, the criterion with the highest weight has been determined as the "social" criterion with the degree of importance 0.325. The fact that the social criterion has the biggest weight for UAVs is acceptable and highlights the significance of increasing public knowledge. Additionally, the fact that these vehicles are designed to serve people alters their use and preference by providing an answer to the question of how social they are. The main criterion with the lowest criterion weight is "Legal and Regulatory" with a significance level of 0.041. The adverse conditions experienced in disaster situations bring many risks and require all precautions to be taken as soon as possible. Considering all these risks, it cannot be expected to meet the legal and regulatory criteria as a priority, therefore it can be reasonably accepted that the relevant criterion is in the last place.
After obtaining the criteria weights, the EDAS approach has been used to rank the determined alternatives. After the criteria weights had been obtained, the EDAS approach was used to rank the determined alternatives. Again, the steps in Section 3.2 have been processed on the criterion-alternative evaluation matrix provided by the decision makers and the importance rankings of the alternatives have been found. Table 8 shows the ranking results for the alternatives.

Table 8. Ranking of Alternatives with the EDAS Method

Alternative	*SP*	*NSP*	*SN*	*NSN*	AS_i	Ranking
A1	0.041	0.242	0.158	0.210	0.226	6
A2	0.107	0.624	0.104	0.483	0.554	5
A3	0.172	1.000	0.135	0.324	0.662	4
A4	0.120	0.700	0.059	0.705	0.703	2
A5	0.051	0.301	0.201	0.000	0.151	7
A6	0.126	0.736	0.012	0.935	0.836	1
A7	0.093	0.540	0.041	0.794	0.667	3

The first alternative that comes to mind is the Jackal-M UAV2 unmanned aerial vehicle. This UAV is one of the vehicles used in the Kahramanmaraş Earthquake in Türkiye on February 6. Jackal-M's communication infrastructure is supported by the Satcom satellite and has begun to be exported to the UK in the international market. This UAV has long hours of flight experience and has the highest flight speed, longest flight range and payload capacity compared to other UAVs. For these reasons, it is not surprising that this alternative is in the first place. Wingcopter 198 (A4) has become the second alternative after Jackal-M UAV2. Last in line was the Foxtech GAIA 190 alternative, which is generally used in last-mile logistics for food supply.

4.1. Comparison Analysis

In this section, comparisons of the results obtained with different MCDM methods are presented.

4.1.1. TOPSIS Method

The TOPSIS method is an MCDM method developed by Hwang and Yoon in 1981 and used in many decision-making problems [30]. The method was developed to make preference rankings based on the basic principle of proximity of decision points to the ideal solution [30], [31]. The steps of the TOPSIS method can be followed in [30]. The criteria alternative evaluations received from experts have been taken as input in the TOPSIS method and a ranking of the alternatives has been obtained again. Table 9 shows the importance rankings for the alternatives as a result of the conducting of the TOPSIS steps.

Table 9. Rankings by TOPSIS Method

Alternatives	S_i^-	S_i^*	C_i^*	Ranking
A1	0.03180	0.06695	0.32203	6
A2	0.06159	0.05082	0.54793	1
A3	0.05744	0.0617	0.48194	5
A4	0.05069	0.05266	0.49045	4
A5	0.02609	0.07642	0.25452	7
A6	0.04569	0.04154	0.52373	2
A7	0.04478	0.04464	0.50080	3

According to the prioritization analysis has been conducted with the TOPSIS method, it is seen that the ranking is found as A2>A6>A7>A4>A3>A1>A5. Alternative A2, with the highest Ci* value, has ranked first, and alternative A5, with the smallest degree of closeness, has ranked last.

4.1.2. COPRAS Method

Complex Proportional Assessment (COPRAS) method is an MCDM method that can evaluate qualitative and quantitative criteria. It has been applied in many areas to rank and evaluate alternatives. The most important feature that distinguishes the COPRAS method from other MCDM methods is to compare the options with each other and reveal as a percentage how much better or worse they are than other options [32], [33]. The steps of the method can be followed in [32]. The results according to the COPRAS method are shown in Table 10.

Table 10. Rankings for COPRAS Method

Alternative	P_i	Q_i	N_i	COPRAS
A1	0.126	0.126	0.792	6
A2	0.143	0.143	0.901	5
A3	0.148	0.148	0.9304	4
A4	0.152	0.152	0.9528	2
A5	0.122	0.122	0.764	7
A6	0.159	0.159	1.000	1
A7	0.150	0.150	0.944	3

Table 10. shows the results and rankings for the COPRAS method and it is seen that the best alternative is A6. It can be seen that the A5 alternative is in the last place. The order of the alternatives is A6>A4>A7>A3>A2>A1>A5.

As a result of the comparative analysis, the A6 alternative, which has come first in the current calculations, has been again ranked first in the COPRAS method and second in the TOPSIS method. The A5 alternative, which has been placed last, is again the last in both the TOPSIS and COPRAS methods. It has been observed that there is no change in the rankings of the A,1 A5 and A7 alternatives. As a result of the comparative analysis, it can be concluded that the results are reliable. Figure 5 shows all the rankings in a chart.

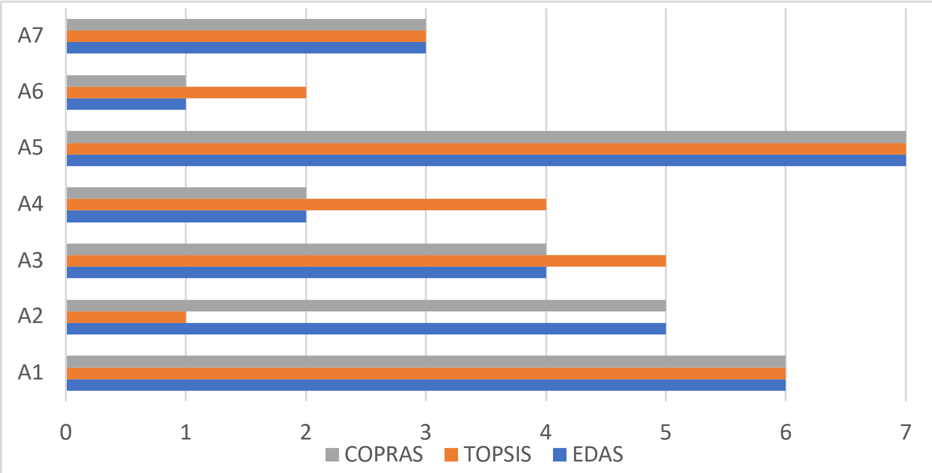

Figure 5. Results for comparison analysis

4.2. Sensitivitiy Analysis

To provide more insight into each selection or ranking methodology, performing sensitivity analysis against several of the assumptions of the base case inputs helps provide a more comprehensive view of the situation. When applying such methods, all sensitivities that provide maximum benefit to the factors driving the selection or ranking should be evaluated [34]. In this study, the criterion weights calculated within the scope of sensitivity analysis were changed and the effect of the change in weights on the results has been examined. Accordingly, the scenarios for the sensitivity analysis are;

Scenario 1 (S1): Interchange the weights of criteria K11, which has the highest criterion weight, and K58, which has the lowest criterion weight.

Scenario 2 (S2): Interchange the weights of criteria K11, which has the largest criterion weight, and K57, which has the next weight from the lowest criterion weight.

Scenario 3 (S3): Swapping the weights of criteria K11, which has the highest criterion weight, and K56, which has the 3rd lowest criterion weight.

Figure 6 shows the changing rankings according to the different scenarios mentioned.

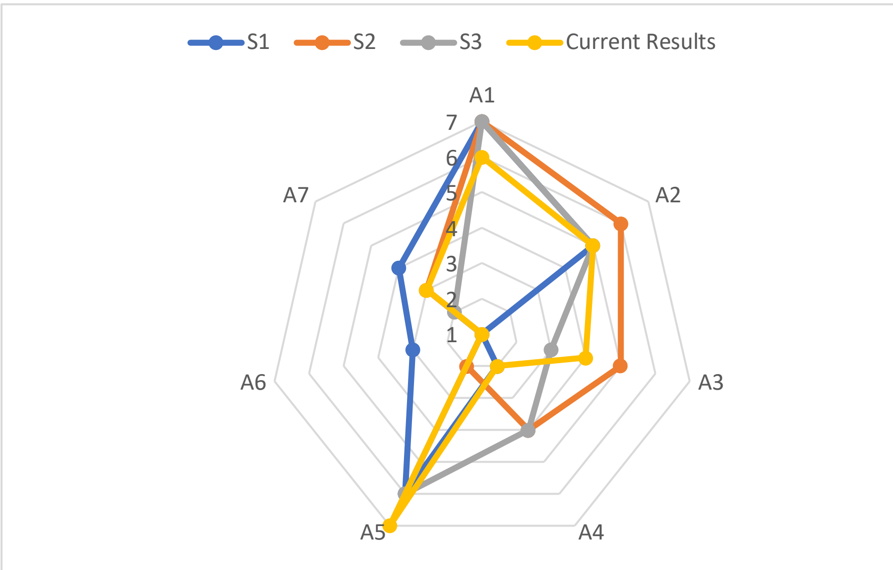

Figure 6. Sensitivity Analysis Results for Different Scenarios

When we examine the sensitivity analysis results, the alternative currently ranked first except for Scenario -1 has been again identified as the first place. Alternative A5, currently ranked the last alternative, has a different ranking only in Scenario-2. Alternatives A3 and A7 have shown different performance rankings for different scenarios and can be stated to be very sensitive to changes in criterion weights. As a result of the sensitivity analysis, it can be claimed that the alternative rankings are affected by the change in the criteria weights, but the results are robust and reliable for our alternative, which is identified in the first place.

5. Conclusions and Future Suggestions

One of the most important topics recently encountered in the literature is the use of UAVs to provide food and medicine to disaster victims in order to save their lives, ensure their health, and thus contribute to the rapid recovery of society. UAVs help minimize the possibility of health risks such as water pollution, food insecurity and hygiene problems after disasters by enabling the timely supply of medicines. In this study, an MCDM analysis has been conducted to determine which UAVs should be used as a priority in order to rapidly supply food and medicine to the areas where they are needed in an emergency or disaster and to provide support for emergency relief operations. The UAVs that can be used for post-disaster food and medicine supply have been determined and a multi-criteria analysis has been proposed regarding which of these UAV alternatives should be used first. This prioritization analysis aims to evaluate the advantages and potential challenges of using UAVs in disaster situations. Seven UAV alternatives that can be used primarily for medicine and food supply in times of disaster have been determined. The criteria that can be utilized to evaluate these UAVs have been revealed and the AHP method has been adopted in weighting these criteria. The EDAS method has been used to evaluate and prioritize the alternatives. As a result of the multi-criteria analysis, the Jackal-M UAV2 alternative has been determined as the aircraft that can be used primarily in post-disaster medicine and food supply. In order to compare the results of the study, COPRAS and TOPSIS methods have been also adopted. Sensitivity analyses have been undertaken to examine the influence of criteria weights on alternative ranking. The reliability and robustness of the results have been explored using comparison and sensitivity studies. For future studies, fuzzy set theory can be adopted to consider the uncertainty in the decision-making process.

Contribution of Researchers

All authors contributed equally to the writing of this article.

Conflicts of Interest

The authors declare that there is no conflict of interest.

Ethics committee approval (if needed)

No need to ethics committee approval statement.

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