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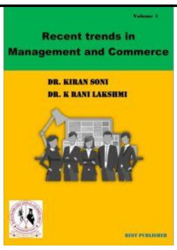

Analysis of the UAV Landing Quality Evaluation Using the TOPSIS Method

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Abstract

The era of automation has arrived. A few decades ago, almost all flying machines were operated by humans. Nowadays, practically all aircraft are either fully automated or on their way there. The advent of features like autopilot is the result of the drive toward complete automation. Unmanned aerial vehicles (UAVs) are powered aircraft without a crew. It employs a gas or electric engine to fly and adheres to the fundamentals of aerodynamics. UAVs are easier to create and cost less to produce than manned aircraft. Compared to traditional manned aircraft, UAVs offer greater flexibility, safety, and mobility. While human aircraft are required to use an airfield, certain UAVs can take off and land without one. We can tell those landing incidents are likely to occur when UAVs are landed thanks to the extensive expert experimentation and historical data on UAV landings. Currently, determining the quality of a UAV landing is primarily based on the experience of the experts or a single metric exceeding the limit, with unavoidably subjective and unscientific findings. This study analyses and improves the unmanned aerial vehicle's landing quality using the MCDM approach TOPSIS. LQ1 is ranked eight, LQ2 is ninth rank, LQ3 is third-ranked, LQ4 is ranked fourth, LQ5 is second-ranked, LQ6 is ranked fifth, LQ7 is ranked sixth, LQ8 is ranked first and LQ9 is seventh-ranked. The result of the landing performance of the unmanned aerial vehicle by using TOPSIS is eighth landing is best followed by the fifth and third.

Keywords: UAV, Landing, pitch angle, ground velocity and MCDM

Introduction

Unmanned aerial vehicles (UAVs) have been quite popular over the past few decades in both military and civilian applications such as aerial photography, tracking, and surveillance. The two primary categories of these UAVs are fixed-wing and rotary-wing, each of which has advantages and disadvantages of its own. [1].The big cabin, excellent flying efficiency, and high cruising speed and altitude of fixed-wing UAVs allow them to perform a variety of jobs that call for the aircraft to carry a heavy payload or have long endurance and range. Fixed-wing UAVs can have limitations, though. Fixed-wing aircraft applications are constrained by the need for a runway or catapult for take-off and landing[2]. But the range and endurance of rotary-wing aircraft are short. The development of a small-scale UAV that can achieve extended flight endurance and range while also taking off and landing vertically is still a difficulty [3].Due to their cheaper cost, greater flexibility, and ease of mobility, unmanned systems have recently seen widespread development. These systems have enormous potential for use in detection, territorial defence, rescue missions, and surveillance, among other things. Unmanned aerial vehicles (UAVs) have become more crucial in disaster relief, naval strikes, and other operations as a representative unmanned system. [4]. The rotorcraft UAV's capability, however, is considerably limited by the speed and endurance limit while performing missions that call for extended endurance or wide-range coverage. As a result, creating an aerial system that combines the benefits of both, operates in a wider envelope (i.e., vertical take-off, transition, cruise, and vertical landing), and contributes to a much wider range of applications is a recently emerging and promising trend in UAV design, particularly for miniature UAVs. The hybrid UAV, also known as a fixed-wing Vertical Take-off and Landing (VTOL) UAV, is created in response to this pressing necessity [5,6].A manned aircraft may experience a catastrophe if a UAV crashes on the ground due to technical problems, but there is 0% likelihood that anyone would perish. UAVs have attracted a lot of interest in the scientific research community because of their life-saving capability and widespread utilisation, especially concerningtheir landing [7].All completely autonomous UAV systems rely on autonomous take-off and landing, which is both their most important and difficult component. In missions involving repeated flight operations and in information collecting and delivery applications, where it is necessary to reach a specific, desired position and then return to a base, the ability to land precisely is crucial. UAV platforms, primarily micro aerial vehicles, must be able to dock autonomously into a recharge station. [8,9]. We can tell those landing incidents are likely to occur when UAVs are landed thanks to the extensive expert experimentation and historical data on UAV landings. Examples of common landing accidents that can be summed up by years of landing experience include tail strikes, damage to the landing gear, the UAV leaving the runway, and the UAV losing control [10]. While the pitch angle, typical acceleration, distance to travel, and ground velocity can all be used to directly reflect these incidences. To evaluate the landing quality, this study chooses the pitch angle, normal acceleration, distance to go, and ground velocity as the evaluation parameters.

Materials and Methods

There have been several improved MCDM approaches established since the 1950s, and they vary from one another in terms of the quantity and quality of new information needed, the methodology utilised, the ease of use, the sensitivity instruments used, and the mathematical properties they check. [11,12].Since real-world decision-making issues are frequently complicated, it is impossible to determine the best course of action by focusing only on one criterion or point of view. Market operation necessitates some understanding of the factors leading to critical circumstances and insolvency. Learning the factors that influence the emergence and demise of workable alternatives is essential. [13].The complexity of economic decisions has expanded significantly over the past few decades, emphasising the significance of creating and utilising sophisticated and effective quantitative analysis approaches to assist and facilitate economic decision-making. [14].

The TOPSIS method uses a ranking system based on how closely a desire resembles the ideal response. This method is currently one of the most used ones for Multiple Criteria Decision Making (MCDM). The TOPSIS approach was primarily developed for use with actual value-only data. When comparing alternatives to local criteria, it can be impossible to give exact scores; as a result, these evaluations are instead thought of as intervals. [15,16].The final alternative should be the one that is furthest from both the positive ideal solution and the negative ideal solution. This is the cornerstone of the TOPSIS method. The theory and applications of TOPSIS have been the subject of numerous publications and papers. [17].

TOPSIS is one of the most well-liked methods for multi-criteria decision analysis. The concept was created by Hwang and Yoon, with Yoon adding to it. This method states that the best choice is the one that is most distant from the negative ideal solution and most near to the positive ideal solution (PIS) (NIS). PIS is a hypothetical option that simultaneously increases the benefit criteria (B) and decreases the cost criteria (C) [18]. While concurrently increasing the cost criteria, NIS simultaneously reduces the benefit criteria. The option with the shortest Euclidean distance from PIS and the greatest distance from NIS is the best choice. After each alternative's proximity coefficient has been calculated in the last stage, the options are arranged using the closeness coefficient (CCi) in descending order. [19].

Step 1: The decision matrix X, which displays how various options perform concerning certain criteria, is created.

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & x \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Step 2: Weights for the criteria are expressed as

$$w_j = [w_1 \cdots w_n], \tag{2}$$

here,$\sum_{j=1}^{n}(w_1 \ \cdots \ w_n) = 1$

Step 3: The matrix x_{ij}'s normalized values are computed as

$$n_{ij} = \frac{x_{ij}}{\sqrt[2]{\sum_{i=1}^{m} x_{ij}^2}} \tag{3}$$

Weighted normalized matrix N_{ij} is calculated by the following formula

$$N_{ij} = w_j \times n_{ij} \tag{4}$$

Step 4: We'll start by determining the ideal best and ideal worst values: Here, we must determine whether the influence is "+" or "-." If a column has a "+" impact, the ideal best value for that column is its highest value; if it has a "-" impact, the ideal worst value is its lowest value.

Step 5: Now we need to calculate the difference between each response from the ideal best,

$$S_i^+ = \sqrt{\sum_{j=1}^{n}(N_{ij} - A_j^+)^2} \qquad \text{For } i \in [1, m] \text{ and } j \in [1, n] \tag{5}$$

Step 6: Now we need to calculate the difference between each response from the ideal worst,

$$S_i^- = \sqrt{\sum_{j=1}^{n}(N_{ij} - A_j^-)^2} \qquad \text{For } i \in [1, m] \text{ and } j \in [1, n] \tag{6}$$

Step 7: Now we need to calculate theCloseness coefficient of i_{th} alternative

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-} \text{Where } 0 \le CC_i \le 1, i \in [1, m] \qquad (7)$$

The Closeness Coefficient's value illustrates how superior the alternatives are in comparison. A larger CC_i denotes a substantially better alternative, whereas a smaller CC_i denotes a significantly worse alternative.

The UAV's landing time determines the quality of the landing to the greatest extent possible, reflecting the largest impact of each flying parameter. As a result, utilising the flight parameters of landing time to assess flight quality is representative [20]. Pitch angle, normal acceleration, distance to fly, and ground velocity of landing time are chosen in this research as significant factors to evaluate the landing quality of UAVs based on the experience of the relevant specialists.

Analysis and Discussion

TABLE 1. Performance rating matrix

	EP1	EP2	EP3	EP4
LQ1	-0.2137	14.68	-109.851	25.229
LQ2	-1.0075	17.76	-152.576	30.131
LQ3	1.4838	15.45	-128.162	28.997
LQ4	1.3107	15.45	-30.5037	28.623
LQ5	1.904	16.99	-128.162	26.974
LQ6	1.2201	19.31	-33.5555	24.77
LQ7	0.7998	20.08	-67.1254	25.292
LQ8	2.0358	13.13	0.01428	28.583
LQ9	-0.0351	16.99	-76.2808	30.094

Table 1 shows the value of the dataset of landing performance of UAVs. Here pitch angle (EP1), normal acceleration (EP2), distance to fly (EP3) and ground velocity of landing time (EP4) is taken as important parameters to evaluate the landing quality of UAV. Here alternative parameters are LQ1, LQ2, LQ3, LQ4, LQ5, LQ6, LQ7, LQ8 and LQ9.

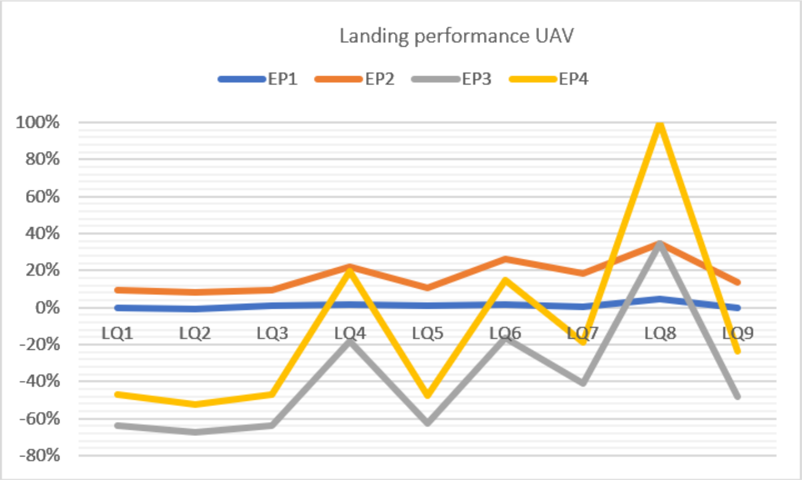

FIGURE 1. Performance ratings

The landing performance of UAVs is represented graphically in this figure 1. Here alternative parameters are LQ1, LQ2, LQ3, LQ4, LQ5, LQ6, LQ7, LQ8 and LQ9. Here pitch angle (EP1), normal acceleration (EP2), distance to fly (EP3) and ground velocity of landing time (EP4) is taken as important parameters to evaluate the landing quality of UAV.

TABLE 2. Normalized Data

-0.01436	0.00579	-0.00136	0.00365
-0.06771	0.00701	-0.00223	0.00436
0.099721	0.0061	-0.00283	0.0042
0.088088	0.0061	-0.00106	0.00414
0.127962	0.00671	-0.0046	0.0039
0.081999	0.00762	-0.00293	0.00359
0.053751	0.00792	-0.0065	0.00366
0.13682	0.00518	2.45E-06	0.00414
-0.00236	0.00671	-0.01311	0.00436

The normalized matrix of the landing performance of UAVs is displayed in Table 2 above. This matrix was produced using equation three.

TABLE 3. Weight

0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

The preferred weight for the evaluation parameters is shown in Table 3. In this case, weights are equally distributed among pitch angle, normal acceleration, distance to fly and ground velocity of landing time. The sum of weights distributed equals one.

TABLE 4. Weighted normalized decision matrix

-0.0036	0.0014	-0.0003	0.0009
-0.0169	0.0018	-0.0006	0.0011
0.02493	0.0015	-0.0007	0.001
0.02202	0.0015	-0.0003	0.001
0.03199	0.0017	-0.0011	0.001
0.0205	0.0019	-0.0007	0.0009
0.01344	0.002	-0.0016	0.0009
0.0342	0.0013	6.1E-07	0.001
-0.0006	0.0017	-0.0033	0.0011

Table 4 shows the weighted normalized matrix of the decision matrix and it is calculated by table 2 and table 3 using equation 4.

TABLE 5. Positive Matrix

0.0342	0.002	6.1E-07	0.0011
0.0342	0.002	6.1E-07	0.0011
0.0342	0.002	6.1E-07	0.0011
0.0342	0.002	6.1E-07	0.0011
0.0342	0.002	6.1E-07	0.0011
0.0342	0.002	6.1E-07	0.0011
0.0342	0.002	6.1E-07	0.0011
0.0342	0.002	6.1E-07	0.0011
0.0342	0.002	-0.0033	0.0011

Table 5 shows the positive matrix calculated by using table 4. The ideal best for a column is the maximum value of that column in table 4.

TABLE 6. Negative matrix

-0.0169	0.0013	-0.0033	0.0009
-0.0169	0.0013	-0.0033	0.0009
-0.0169	0.0013	-0.0033	0.0009
-0.0169	0.0013	-0.0033	0.0009
-0.0169	0.0013	-0.0033	0.0009
-0.0169	0.0013	-0.0033	0.0009
-0.0169	0.0013	-0.0033	0.0009
-0.0169	0.0013	-0.0033	0.0009
-0.0169	0.0013	-0.0033	0.0009

Table 6 shows the negative matrix calculated by using table 4. The Ideal best for a column is the minimum value in that column in table 4.

TABLE 7. SI Plus and Si negative

	SI Plus	Si Negative
LQ1	0.0378	0.013658
LQ2	0.0511	0.002766
LQ3	0.0093	0.041938
LQ4	0.0122	0.039067
LQ5	0.0025	0.048967
LQ6	0.0137	0.037519
LQ7	0.0208	0.030419
LQ8	0.0007	0.051238
LQ9	0.0348	0.016344

Table 7 shows the Si plus and Si negative values. difference of each response from the ideal best (S_i^+) is calculated using equation 5 and the difference between each response from the ideal worst (S_i^-) is calculated using equation 6.

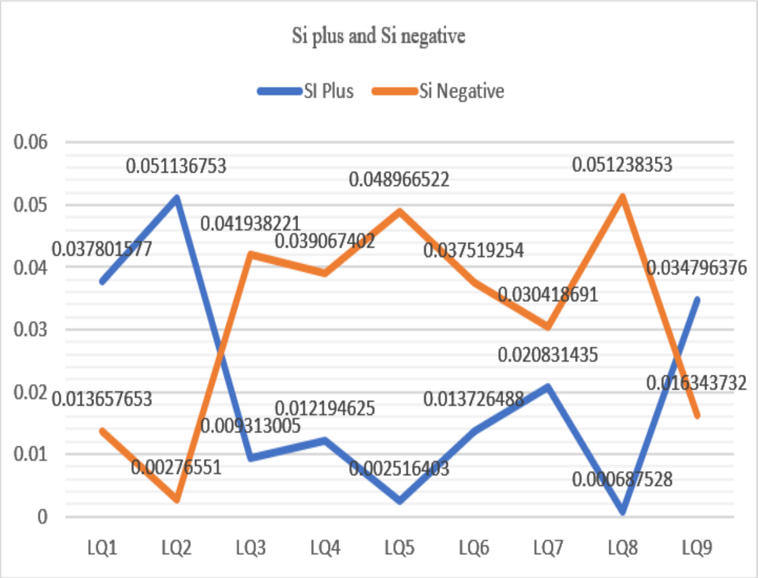

FIGURE 2. SI Plus and Si negative

Figure 2 illustrates the graphical representation of the Si plus and Si negative values. difference of each response from the ideal best (S_i^+) is calculated using equation 5 and the difference between each response from the ideal worst (S_i^-) is calculated using equation 6.

TABLE 8. Closeness coefficient

	Ci
LQ1	0.2654
LQ2	0.0513
LQ3	0.8183
LQ4	0.7621
LQ5	0.9511
LQ6	0.7321
LQ7	0.5935
LQ8	0.9868
LQ9	0.3196

The proximity coefficient values of the alternatives are displayed in Table 8. Equation 7 is employed in the calculation. Here Closeness coefficient value for LQ1 is 0.2654, LQ2 is 0.0513, LQ3 is 0.8183, LQ4 is 0.7621, LQ5 is 0.9511, LQ6 is 0.7321, LQ7 is 0.5945, LQ8 is 0.9868 and LQ9 is 0.3196.

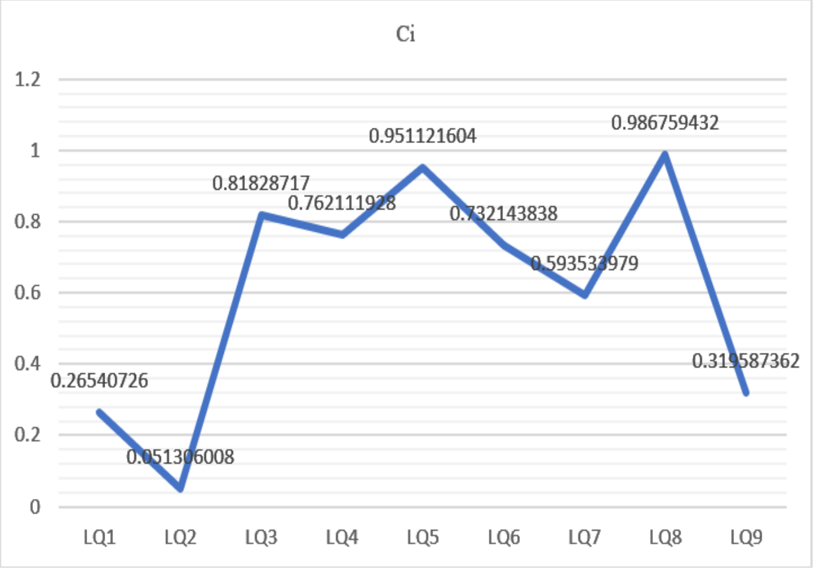

FIGURE 3. Closeness Coefficient (CCi)

Figure 3 illustrates the graphical representation of CCi. It is calculated by using equation 7. Here Closeness coefficient value for LQ1 is 0.2654, LQ2 is 0.0513, LQ3 is 0.8183, LQ4 is 0.7621, LQ5 is 0.9511, LQ6 is 0.7321, LQ7 is 0.5945, LQ8 is 0.9868 and LQ9 is 0.3196.

TABLE 9. Rank

	Rank
LQ1	8
LQ2	9
LQ3	3
LQ4	4
LQ5	2
LQ6	5
LQ7	6
LQ8	1
LQ9	7

Table 9 shows the rank of landing performance of UAVs. Here ranking of alternatives: LQ1 is ranked eight, LQ2 is the ninth rank, LQ3 is third-ranked, LQ4 is ranked fourth, LQ5 is second-ranked, LQ6 is ranked fifth, LQ7 is ranked sixth, LQ8 is ranked first and LQ9 is seventh-ranked.

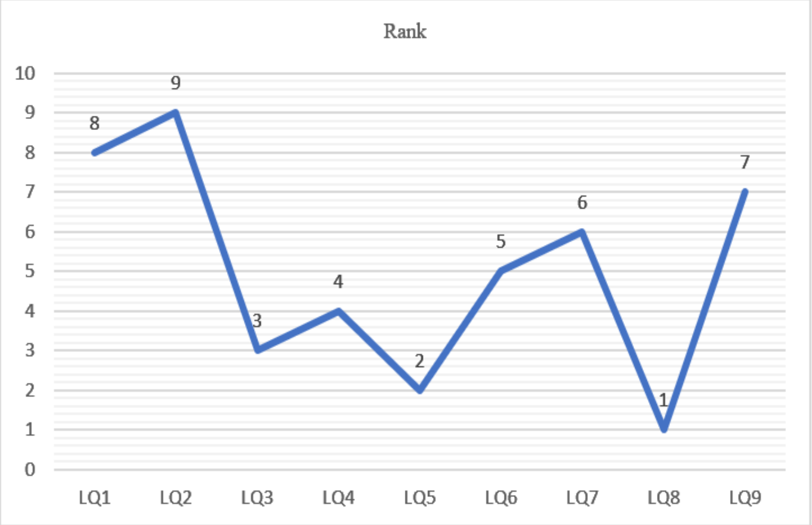

FIGURE 4. Rank

Figure 4 illustrates the ranking of Ui from Table 9. Here rank of alternatives using the TOPSIS method for LQ1 is ranked eighth, LQ2 is the ninth rank, LQ3 is third-ranked, LQ4 is ranked fourth, LQ5 is second-ranked, LQ6 is ranked fifth, LQ7 is ranked sixth, LQ8 is rank first and LQ9 is seventh-ranked. The result of the landing performance of the unmanned aerial vehicle by using TOPSIS is eight landings is best followed by the fifth and third.

Conclusion

Due to their cheaper cost, greater flexibility, and ease of mobility, unmanned systems have recently seen widespread development. These systems have enormous potential for use in detection, territorial defence, rescue missions, and surveillance, among other things. Unmanned aerial vehicles (UAVs) have become more crucial in disaster relief, naval strikes, and other operations as a representative unmanned system.The hazard of the landing phase is demonstrated by the high incidence of aviation accidents. The flight condition (speed, altitude, course, etc.), the shape of the aircraft, and the state of the engines all significantly alter during the landing phase, which makes landing mishaps more likely. Additionally, fixed-wing UAVs are more likely to have landing mishaps than unmanned helicopters and multi-rotor UAVs. The unmanned helicopter and multi-rotor UAV's vertical take-off and landing are the cause.UAV landing quality represents how well or poorly the UAV performed the landing operation. A smooth, safe landing and complete stop are possible for UAVs with good landing quality; in contrast, low landing quality can result in a runway overrun, heavy landing, and other risky situations for UAVs. In this paper, the TOPSIS method is used to optimize the landing quality of the unmanned aerial vehicle. The result of the landing performance of the unmanned aerial vehicle by using TOPSIS is eight landings is best followed by the fifth and third.

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