Comprehensive evaluation of Logistics Delivery Unmanned Aerial Vehicles Based on Entropy Method

Ziang Zhang*, Minghai Lv*

College of Business Administration, Liaoning Technical University, Huludao, Liaoning, 125105, China
1264008789@qq.com,845721911@qq.com

Abstract. With the continuous progress of technology, unmanned aerial vehicles(uav) delivery, as a new logistics mode, has gradually attracted people's attention. Compared with traditional delivery methods, UAV delivery has advantages such as fast speed, low cost, and high flexibility. However, due to many challenges faced by UAV delivery in practical applications, such as weather conditions, delivery time, and geographical environment, an evaluation model is needed to assess the adaptability of UAVs for logistics delivery. Based on a summary of domestic and foreign research and a survey of mature civil UAVs in China, this paper uses the entropy method to construct an evaluation system for the safety, delivery capability and application control of logistics delivery UAVs for comprehensive evaluation. Based on the results of the evaluation, a more reasonable evaluation model for logistics delivery UAVs is proposed, providing reference for the development of UAV delivery in logistics enterprises in China.

Keywords: Logistics delivery, comprehensive evaluation, entropy method, unmanned aerial vehicles (UAVs)

1 INTRODUCTION

With the rapid development of e-commerce and continuous progress in the logistics industry, traditional manual delivery methods have become insufficient to meet the growing logistics demand. In this context, drone technology has received widespread attention as an innovative delivery method. Drones, as autonomous unmanned aerial vehicles, possess advantages such as flight flexibility, low cost, and high efficiency, making them powerful tools to address the bottlenecks in logistics delivery[1].

The "last mile" in the logistics field is the most complex and time-consuming part of delivery, involving issues such as traffic congestion, low manpower availability, and uncertain delivery times. Drone delivery can effectively alleviate these problems and, under ideal conditions, save up to 60% of costs. Furthermore, logistics drones can reach geographically challenging areas, reducing labor costs[2]. However, with the wide variety and complexity of drone models available, selecting the appropriate drone has become a primary concern.

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2 LITERATURE REVIEW

The research objective of this article is to solve the "last mile" problem in logistics challenges by establishing an evaluation model for drone logistics distribution. It provides a reference for the development of the logistics field. XU Jianhua[3] unavoidable emergencies can occur during drone operations, and it is necessary to focus on solving aircraft control and decision-making issues under all potential accidents. YUAN Ziyi[4] thinks that the battery life of drones is a very critical issue, It is a key indicator of the performance of drones. As it limits the range of delivery services and affects the efficiency of distribution. Luo Jing[5] and others, aiming to better extract valuable information from drone flight trajectories and accurately and objectively evaluate the quality of drone flights based on trajectory data, have proposed a CNN-BiLSTM network model. He believes the operability of drones is also very important. XV Jiaxin[6] and others believe that the main issue with drones is the safety concern, which threatens aviation security and people's privacy. Sun Jie[7] suggests that the improvement in the timeliness of drone delivery is the most obvious change brought about by unmanned technology to logistics distribution. Logistics drones, with their high delivery efficiency and timeliness, can meet consumer demands. Dai Zhenjun[8] considers battery capacity to be the key factor in the delivery time and capability of drones. Moreover, the strength of sensing abilities and avoidance capabilities are important technical skills that determine the safety of the drone delivery process. Zhang Fang et al.[9], taking into account drone performance and airspace restrictions, have established a multi-stage logistics drone demand forecasting model. The model utilizes a combination forecasting method and dynamic allocation algorithm to calculate the demand for drones in the "last mile" delivery.

Taking into account the above literature, there are many factors to consider when using drones as tools for logistics delivery. This paper aims to analyze the requirements for drone delivery, explore evaluation models, establish evaluation indicators, and thus develop an evaluation system suitable for logistics drone delivery. The goal is to provide a reference for the future application of drones in logistics delivery.

3 RESEARCH ON THE CONSTRUCTION OF EVALUATION MODEL

3.1 Establishment of Evaluation Criteria

Comprehensive consideration is needed in the evaluation research of logistics delivery UAVs. Based on an extensive review of journal literature, this paper summarizes three evaluation directions:

Safety: Dai Zhenjun pointed out in his research on UAV development that UAVs may cause safety accidents when facing severe weather, deliberate obstruction, or accidents. Therefore, obstacle avoidance capability is crucial for UAVs. Wang Huanhuan analyzed UAV accidents reported in the news and emphasized the importance for manufacturers to strengthen self-protection and obstacle avoidance capabilities of UAVs from the perspective of production, market entry, and use. This article determines the maximum wind resistance speed, working environment temperature, visual obstacle perception range, infrared obstacle perception range, horizontal field of view, and vertical field of view for logistics delivery unmanned drones.

Adaptability: Zhang Fang et al. proposed that payload capacity and endurance are important indicators for determining whether UAVs can meet delivery demands. Dai Zhenjun believes that UAV companies should strive to improve payload capacity beyond the limitations of transporting only lightweight items. Xu Jiaxin, Zeng Lingwei, and others argue that if communication fails, UAVs will lose control, leading to safety accidents. The effective range of remote control signals is a key indicator for determining whether UAVs are suitable for delivery in remote areas. This article will evaluate logistics delivery unmanned drones based on the maximum signal effective distance, maximum flight altitude, battery capacity, and unit price.

Efficiency: Wang Lie believes that flight capabilities of UAVs affect their transport efficiency. The author evaluated and analyzed the flight speed, endurance time, and maximum range of UAVs. Luo Jing believes that flight capabilities are crucial for UAVs. Gu Cheng proposed optimizing the logistics delivery system, establishing dedicated UAV maintenance departments, improving the quality of UAVs, and fundamentally enhancing delivery efficiency when analyzing the main influencing factors of logistics delivery. Wang Lei suggested that UAVs can enhance logistics delivery efficiency and speed, reduce charging time, save costs, and be environmentally friendly when analyzing the prospects of UAV delivery. Kong Jie believes that UAVs are beneficial for end-point delivery operations in remote areas, improving the timeliness and reducing costs of delivery services. The maximum flight speed, maximum flight time, maximum payload, and maximum charging power can be used as evaluation criteria in this article.

Please refer to Table 1 for all evaluation criteria:

Table 1. Evaluation index system for logistics and delivery unmanned aerial vehicles

Logistics delivery drone evaluation index system（A）	Safety（B1）	maximum wind resistance speed（C1） operating environment temperature(C2) visual obstacle perception range(C3) infrared obstacle perception range(C4) horizontal field of view(C5) vertical field of view(C6)
	adaptability（B2）	maximum signal effective distance(C7) maximum flight altitude(C8) battery capacity(C9) Unit price(C10)
	efficiency（B3）	maximum flight speed(C11) speed, maximum flight time(C12) maximum payload capacity(C13) maximum charging power(C14)

3.2 Determination of Evaluation Method

The Delphi method, Analytic Hierarchy Process, and Fuzzy Comprehensive Evaluation are highly subjective. These methods are not suitable for the objective evaluation required in this paper.

The TOPSIS method is suitable for situations where there are positive and negative effects among indicators and when considering the best and worst solutions, not suitable.

After comprehensive consideration, this paper decides to use the Entropy Method as the evaluation method. The Entropy Method determines weights objectively by analyzing the distribution of indicator values, thereby reducing the impact of subjective human factors. After processing the data, we will use the Entropy Method to determine the information entropy of each index, and thus, find out the weight of each indicator, which will allow us to carry out a comprehensive evaluation of the drones.

4 INTRODUCTION OF EXAMPLES

In this article, we have selected the drones from the leading Chinese drone manufacturer, DJI Innovations, for evaluation. This is because DJI Innovations has a high level of technological expertise and innovation capability. As there are currently few drones specifically designed for logistics transportation, we have chosen six drones based on the basic requirements of logistics delivery. Due to the complexity of their models, we will refer to them as M1-M6.

4.1 Establishing the Initial Matrix

All the technical parameters of the drones used in Table 2 of this article are sourced from the official website of DJI Innovations.

Table 2. Technical Parameters of the Drones

	M1	M2	M3	M4	M5	M6
C1（m/s）	12	12	12	8	12	12
C2（°）	-20～40	-20～45	-20～45	-10～40	-20～45	-20～50
C3（m）	0.7～40	0.7～30	0.7～30	0.7～30	0.7～40	1～50
C4（m）	0.1～8	0～5	0～5	0～5	1.5～50	0.1～8
C5(°)	65	60	60	60	90	75
C6（°）	50	45	45	54	106	60
C7（km）	20	7	7	5	20	15

C8（km）	5	3	3	4.5	6	5
C9（mah）	23520	8560	15320	34200	76000	11870
C10（yuan）	72328	39999	49999	38000	125000	49359
C11（m/s）	23	23	18	18	20	23
C12（min）	55	27	38	40	18	55
C13（kg）	2.37	2.34	1.57	5.5	30	2.7
C14（w）	992	360	360	600	5700	992

Translate to English: In the evaluation criteria, the values assigned to the three criteria C2, C3, and C4 are represented as a numerical range, and they are calculated based on their difference. A larger difference indicates better performance. This results in the initial matrix D1.

$$D_1 = \begin{bmatrix} 12.0 & 60.0 & 39.3 & 7.9 & 65.0 & 50.0 & 20.0 & 5.0 & 23520.0 & 72328.0 & 23.0 & 55.0 & 2.4 & 992.0 \\ 12.0 & 35.0 & 29.3 & 5.0 & 60.0 & 45.0 & 7.0 & 3.0 & 8560.0 & 39999.0 & 23.0 & 27.0 & 2.3 & 360.0 \\ 12.0 & 65.0 & 29.3 & 5.0 & 60.0 & 45.0 & 7.0 & 3.0 & 15320.0 & 49999.0 & 18.0 & 38.0 & 1.6 & 360.0 \\ 8.0 & 50.0 & 29.3 & 5.0 & 60.0 & 54.0 & 5.0 & 4.5 & 3420.0 & 38000.0 & 18.0 & 40.0 & 5.5 & 600.0 \\ 12.0 & 65.0 & 39.3 & 48.0 & 90.0 & 106.0 & 20.0 & 6.0 & 76000.0 & 125000.0 & 20.0 & 18.0 & 30.0 & 5700.0 \\ 12.0 & 70.0 & 49.0 & 7.9 & 75.0 & 60.0 & 15.0 & 5.0 & 11870.0 & 49359.0 & 23.0 & 55.0 & 2.7 & 992.0 \end{bmatrix}$$

4.2 Evaluation Calculation

Data Standardization. Considering that each criterion has a different meaning, not all criteria have higher values indicating better performance. On the contrary, some criteria are more desirable to have lower values for the drones to be more suitable for logistics delivery operations, such as price. Therefore, the criteria will be standardized as follows: $x'_{ij} = \frac{x_{ij} - \min(x_{1j}, x_{2j}, \cdots x_{nj})}{\max(x_{1j}, x_{2j}, \cdots x_{nj}) - \min(x_{1j}, x_{2j}, \cdots x_{nj})}$ For criteria with positive feedback values, the following calculation will be performed: $x'ij = \frac{\min(x_{1j}, x_{2j}, \cdots x_{nj}) - x_{ij}}{\max(x_{1j}, x_{2j}, \cdots x_{nj}) - \min(x_{1j}, x_{2j}, \cdots x_{nj})}$ For criteria with negative feedback values, the following calculation will be performed: Then, all the data will be standardized. After standardization, the values cannot be zero, so a shift transformation will be applied with a shift value of 0.001. The result will be D2.

$$D_2 = \begin{bmatrix} 1.001 & 0.501 & 0.509 & 0.068 & 0.168 & 0.083 & 1.001 & 0.668 & 0.223 & 0.606 & 1.001 & 1.001 & 0.029 & 0.119 \\ 1.001 & 0.751 & 0.001 & 0.001 & 0.001 & 0.001 & 0.134 & 0.001 & 0.001 & 0.978 & 1.001 & 0.244 & 0.028 & 0.001 \\ 1.001 & 0.751 & 0.001 & 0.001 & 0.001 & 0.001 & 0.134 & 0.001 & 1.001 & 0.863 & 0.001 & 0.542 & 0.001 & 0.001 \\ 0.001 & 0.001 & 0.001 & 0.001 & 0.001 & 0.149 & 0.001 & 0.501 & 0.381 & 1.001 & 0.001 & 0.596 & 0.139 & 0.046 \\ 1.001 & 0.751 & 0.509 & 1.001 & 1.001 & 1.001 & 1.001 & 1.001 & 1.001 & 0.001 & 0.401 & 0.001 & 1.001 & 1.001 \\ 1.001 & 1.001 & 1.001 & 0.068 & 0.501 & 0.247 & 0.668 & 0.668 & 0.050 & 0.870 & 1.001 & 1.001 & 0.041 & 0.119 \end{bmatrix}$$

Determining the Contribution Ratio of Criteria. The standardized matrix D2 will be used in the contribution ratio formula $P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}$ to obtain matrix D3.

$$D_3 = \begin{bmatrix} 0.200 & 0.133 & 0.252 & 0.059 & 0.100 & 0.056 & 0.341 & 0.235 & 0.127 & 0.140 & 0.294 & 0.296 & 0.024 & 0.093 \\ 0.200 & 0.200 & 0.000 & 0.001 & 0.001 & 0.001 & 0.046 & 0.000 & 0.001 & 0.226 & 0.294 & 0.082 & 0.023 & 0.001 \\ 0.200 & 0.200 & 0.000 & 0.001 & 0.001 & 0.001 & 0.046 & 0.000 & 0.058 & 0.200 & 0.000 & 0.016 & 0.001 & 0.001 \\ 0.000 & 0.000 & 0.000 & 0.001 & 0.001 & 0.100 & 0.000 & 0.176 & 0.217 & 0.232 & 0.000 & 0.176 & 0.112 & 0.036 \\ 0.200 & 0.200 & 0.252 & 0.879 & 0.598 & 0.676 & 0.341 & 0.353 & 0.570 & 0.000 & 0.118 & 0.000 & 0.808 & 0.777 \\ 0.200 & 0.267 & 0.495 & 0.059 & 0.300 & 0.167 & 0.227 & 0.235 & 0.028 & 0.201 & 0.294 & 0.296 & 0.033 & 0.093 \end{bmatrix}$$

Calculating Entropy Value. Matrix D3 will be used in the calculation formula,$e_j = -k \star \sum_{i=1}^{n} p_{ij} \ln(p_{ij}).k = \frac{1}{ln(m)} > 0$，$0 \leq e_j \leq 1$.The k value of 0.558 is obtained because the m sample format is 6.The e_j value obtained from the calculation will be input into the formula for calculating the coefficient of variation:$g_j = 1 - e_j$.Then, the coefficient of variation g_j is input into the formula for calculating the weight values:$w_j - \frac{g_j}{\sum_{i=1}^{n} g_j} (j = 1,2,..m)$.This yields the weight values for each indicator, as in Table 3.

Table 3. Entropy Values, Coefficients of Variation, and Weight Values of Each Criterion

	Safety						adaptability				efficiency			
Indicators	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
Entropy value(e_j)	0.899	0.887	0.588	0.261	0.509	0.539	0.756	0.759	0.661	0.891	0.746	0.844	0.396	0.428
Coefficient of variation(g_j)	0.101	0.113	0.412	0.739	0.491	0.461	0.244	0.241	0.339	0.109	0.254	0.156	0.604	0.572
Weight (w_j)	0.021	0.023	0.085	0.153	0.102	0.095	0.050	0.050	0.070	0.022	0.053	0.032	0.125	0.118

Linear Weighting Method. After obtaining the weight values of each criterion, the linear weighting method will be applied: $\mathrm{u_i} = \sum_{\mathrm{i}=1}^{\mathrm{n}} w_j x_{ij}$. This will result in the overall scores of the six drones, as shown in Table 4

Table 4. Overall Scores of the Six Drones for Logistics Delivery Operations

	M1	M2	M3	M4	M5	M6
Overall score	0.326	0.131	0.089	0.130	0.866	0.407

According to the comprehensive scores of these six drones, it can be seen that M3 has the lowest score of 0.089, while M5 has the highest score of 0.886. M5 is the latest drone specifically designed for logistics delivery by DJI, which indirectly verifies the effectiveness of the method. If the logistics company has a sufficient budget, purchasing the M5 drone would be the optimal choice. On the other hand, M3 has the lowest score, indicating that its indicators are relatively low and it is less suitable for logistics delivery.

Based on the calculated weight values, it can be observed that five indicators, namely C4, C5, C6, C13, and C14, have higher weights. Three of them are related to safety indicators, while the other two are related to efficiency indicators. After calculation, the weight of safety is 0.474, indicating that drone manufacturers should prioritize safety when developing logistics delivery drones. C13 and C14 represent the delivery capability of the drone. If some performance needs to be sacrificed in the drone's design, it is possible to consider sacrificing C12 since it has a lower weight. In terms of applicability, three indicators, C7, C8, and C9, have higher weights, while C10 has a lower weight. This suggests that drone R&D companies can focus on enhancing the technological level of their products without much concern for the unit price. The overall weight of efficiency is 0.328, while the weight of applicability is 0.192. There is a significant difference in weight values among the three aspects, indicating the need to seek a balance. Therefore, in the future design, selection, and optimization of logistics delivery drones, it is crucial to prioritize and ensure the maximum consideration and guarantee of safety. At the same time, continuous improvement of efficiency and applicability is necessary to ensure high-quality and reliable logistics delivery services.

5 CONCLUSION

This article focuses on the research of domestic drones that are currently available for sale, establishing evaluation criteria in three aspects: safety, applicability, and efficiency. The entropy method is used for calculation to analyze the importance of various indicators of logistics delivery drones, and the following conclusions are drawn.

Firstly, when researching and developing logistics delivery drones, priority should be given to safety. In terms of applicability and efficiency, a balance needs to be struck.

Secondly, in terms of safety, the infrared perception range is an important technical aspect. While ensuring the transportation capability of logistics delivery drones, developing the infrared perception range can enhance the comprehensive market competitiveness of enterprises' drones.

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