Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 5, No. 3, 2023

Research on Evaluation Method of Unmanned Reconnaissance Equipment

Fanshan Yu[1, *]

[1]College of Equipment Management and Support, Engineering University of PAP, Xi'an, 710086, China
[*] **Corresponding author**: 1059692689@qq.com

Abstract: Unmanned reconnaissance equipment has promoted the advancement of unmanned reconnaissance technology, but its rapid development has brought higher requirements for performance, cost, reliability, safety and other aspects. Among many evaluation methods, Analytic Hierarchy Process (AHP), Fuzzy Comprehensive Evaluation (FCE), and Multi-Attribute Decision Making (MADM) are widely used evaluation methods. AHP is a commonly used evaluation method, which has strong comprehensiveness and can fully consider index factors; FCE evaluates from different perspectives and has certain flexibility; MADM comprehensively considers the interrelationships and influences among indicators and can avoid the influence of individual experience factors of decision-makers. However, in practical applications, the evaluation results of a single method may be biased. This article summarizes and reviews the above evaluation methods. Firstly, it introduces the current development status of unmanned reconnaissance equipment. Then, it introduces various evaluation methods. Next, it introduces the application of unmanned reconnaissance equipment in different fields. Finally, it summarizes the advantages and disadvantages of various evaluation methods and prospects for the evaluation research of unmanned reconnaissance equipment. The aim of this article is to provide reference and inspiration for researchers in related fields.

Keywords: Unmanned equipment, Reconnaissance equipment, Evaluation methods.

1. Introduction

Unmanned reconnaissance equipment has the characteristics of unmanned driving, platform adaptability, and autonomous collaboration, which make it an important force on the future battlefield. However, there are uncertainties in its combat capability, reliability, and safety, so it is necessary to conduct a comprehensive evaluation of unmanned reconnaissance equipment. Evaluation methods can comprehensively consider indicator factors and impacts, providing decision-makers with scientific and reasonable bases to make decisions. With the development of technology, the types of unmanned reconnaissance equipment continue to increase, and their requirements for comprehensive performance are also getting higher. For example, the combat effectiveness of unmanned reconnaissance aircraft depends not only on the endurance of the drone but also on whether it can complete long-term, large-scale, and high-precision reconnaissance tasks. Therefore, a comprehensive evaluation of unmanned reconnaissance aircraft is of great significance.

Currently, there are mainly Analytic Hierarchy Process (AHP), FuzzySet-off, and Multi-Agent Decision Making Method (MDIM) for evaluating unmanned reconnaissance equipment. These evaluation methods comprehensively consider indicator factors and impacts from different perspectives, with certain flexibility and specificity, but single-method evaluation results may have deviations. With the development of artificial intelligence, deep learning-based evaluation methods for unmanned reconnaissance equipment have begun to be applied, such as neural network-based evaluation methods, which extract the characteristics of unmanned reconnaissance equipment through deep learning and input them into the neural network model. After training, the unmanned reconnaissance aircraft can independently complete reconnaissance tasks under specific conditions by learning from the data.

The application of unmanned reconnaissance equipment is gradually becoming widespread. For example, when unmanned reconnaissance aircraft cooperate with manned aircraft to carry out joint operations, they will form an operational system with unmanned aircraft as the core and manned aircraft as support. The use of artificial intelligence technology can realize the coordinated operation of unmanned and manned aircraft. When unmanned aerial vehicles cooperate with unmanned vehicles for joint operations, it can effectively improve operational effectiveness, etc.

The development of unmanned aerial vehicles has become a focus of attention worldwide, and unmanned reconnaissance aircraft, as an important branch of unmanned aerial vehicles, plays an increasingly important role on the battlefield. However, due to the many factors considered during the design of unmanned reconnaissance aircraft, the large dimensional space of indicators, and the complexity of the relationships between indicators, the evaluation of unmanned reconnaissance aircraft is not an easy task.

Currently, research on the evaluation of unmanned reconnaissance aircraft is relatively scarce, mainly focused on unmanned aerial vehicles. In the comprehensive evaluation of unmanned reconnaissance aircraft, existing research mainly focuses on evaluating its combat effectiveness, reliability, and safety..

2. Development Status of Unmanned Reconnaissance Equipment.

Unmanned reconnaissance equipment is a platform that uses autonomous flight or remote control to perform intelligence gathering, surveillance, reconnaissance and other tasks in the air or on the ground with human support. Currently, the US military has realized the application of unmanned reconnaissance equipment in multiple fields, such as drones, unmanned submersibles, unmanned ships, etc. At present, countries all over the world are developing unmanned reconnaissance equipment, and China has also formulated a "roadmap for the development of unmanned reconnaissance aircraft," clarifying the technical indicators of unmanned reconnaissance aircraft. Currently, the US, Russia and other countries are in a leading position in the field of unmanned reconnaissance aircraft, and there is a trend towards multi-platform development.

For example, the X-47B unmanned reconnaissance aircraft and X-47B "Greyhound" UAV in the US, the "Yakhont" UAV in Russia, the Rainbow-5 UAV and "Wing Loong" -1 UAV in China, the "Heron" UAV and "Reaper" UAV in Israel and so on.

Among them, the X-47B is a multi-tasking unmanned combat platform that uses advanced composite material wings and metal structures to reduce weight to a certain extent; it uses advanced engines to increase flight speed while reducing fuel consumption; it can execute various combat missions, including reconnaissance, monitoring and target indication, and has good aerodynamic design, can carry a variety of weapon systems, has strong stealth performance and low detectability, and has radar and infrared sensors at the connection between the fuselage and wings, which can hide itself well. The mission capabilities of the X-47B include unmanned reconnaissance, monitoring and target indication; reconnaissance and air refueling; battlefield environment awareness, intelligence collection and analysis; land attack, and so on.

In addition, Russia is also actively developing a series of drone equipment. In March 2018, the Russian Ministry of Defense publicly announced the flight data of a new "Orion" drone; in July of the same year, the Russian Aerospace Forces used the "Dagger" hypersonic missile to strike targets in Syria for the first time; and in August, the "Dagger" hypersonic missile successfully completed its first flight test. On February 20, 2020, the Russian Deputy Minister of Defense stated that the "Dagger" hypersonic missile system of the Russian military has completed its first flight test. From March 16 to 17, 2020, the Russian Aerospace Forces and Rocket Forces organized a hypersonic missile test activity in the southern military district of Russia. The missile is Russia's fourth-generation heavy hypersonic weapon system, mainly used to attack enemy warheads and other targets.

3. Review of Assessment Methods

In recent years, with the continuous development of unmanned reconnaissance equipment, various evaluation methods have been widely applied to the performance evaluation of unmanned reconnaissance equipment. Currently, common evaluation methods for unmanned reconnaissance equipment include the analytic hierarchy process (AHP), fuzzy comprehensive evaluation method, and multi-attribute decision-making method. Based on existing research results, we summarize the advantages and disadvantages of these evaluation methods.

AHP: AHP is a commonly used systematic analysis method that decomposes a complex problem into multiple levels according to nature and relationships, and quantifies the relative importance between factors to reach a decision. Its feature is the combination of qualitative and quantitative methods, which follows the rules of thinking and psychology for hierarchical and quantitative processing. This method is widely applied in decision analysis in fields such as society and economy.

Specifically, AHP mainly includes the following steps: first, decompose the problem into multiple factors and form a multi-level structural model; second, determine the relative importance between the factors through expert judgment or experience and assign weights; then calculate the consistency of weights among the factors and adjust inconsistent weights; finally, calculate the final decision result based on the weight of each factor. The advantages of AHP include its ability to decompose the decision problem into multiple hierarchical structural models, rank them according to importance, and thus rationalize and systematize the decision-making process to achieve more scientific and accurate decisions. AHP can combine quantitative and qualitative decision factors, quantify the relationships and weights between factors, and thus provide a more objective analysis and decision. This method can also form teams using various methods like expert experience and collective wisdom, thereby enhancing the effectiveness and quality of the decision-making process. The following formula is required:

$$w = [w_1, w_2, \ldots, w_n]$$

$$w_i = \frac{\sum_{j=1}^{n} b_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}}$$

The disadvantages of AHP mainly include the requirement of comparability between multiple decision factors, but some factors may have non-quantifiable characteristics, such as cultural background and social atmosphere, which are difficult to measure uniformly and may affect the rationality of the decision. AHP requires a large amount of data support, and if the data is insufficient or of poor quality, it may lead to inaccurate decision results. The subjective factors of humans have a greater impact on weight assignment, and thus subjectivity may exist in the weight assignment process, which reduces the objectivity and accuracy of the decision.

Fuzzy Comprehensive Evaluation Method: Fuzzy comprehensive evaluation method is a method that calculates the scores or levels of the evaluated object by calculating the membership degree of multiple factors. This method uses the fuzzy system method to unify the weights and membership degrees of various indicators, and obtain a comprehensive evaluation result. Its specific implementation steps include determining the indicator system, establishing a multi-level evaluation model, determining the membership degree function of the evaluation factors, constructing the evaluation matrix, calculating the indicator weights and evaluation scores, etc. The advantages of the fuzzy comprehensive evaluation method include its ability to consider more comprehensively the impact of multiple factors on the evaluated object, and reflect more objectively and realistically during the evaluation process. It can integrate and process different types of indicators, avoiding conflicts and contradictions between indicators. By determining the weights of various indicators, it can accurately reflect their importance, which is helpful for formulating scientific development strategies and decisions. The following formula is required:

$$R=\frac{\sum_{j=1}^{m}\left(\prod_{i=1}^{n}k_{ij}^{wi}\right)\cdot x_j}{\sum_{j=1}^{m}\left(\prod_{i=1}^{n}k_{ij}^{wi}\right)}$$

The disadvantages of the fuzzy comprehensive evaluation method include possible subjectivity in the selection of parameters such as weight and membership degree of the indicators, leading to deviation in the evaluation result. This evaluation method may be relatively complex, requiring certain professional knowledge and skills in calculation methods and model building. Its applicability to different fields and evaluation objects may be limited, requiring different adjustments and improvements for different scenarios.

Multi-attribute decision-making method is a method used to make decisions for a problem involving multiple attributes or factors. It assigns weights to each attribute, integrates the numerous attributes, and obtains the best decision solution.

Multi-attribute decision-making methods can be divided into static and dynamic methods. Static multi-attribute decision-making methods include weighted method, TOPSIS, grey theory, while dynamic methods include AHP, fuzzy comprehensive evaluation method, principal component analysis, etc. The advantages of multi-attribute decision-making method include its ability to integrate multiple decision factors to produce relatively objective and scientific decision results. It can adapt to different types of problems by selecting different methods according to the actual situation, thereby improving the accuracy and reliability in problem-solving. It can effectively correct and manage the subjective thinking of decision-makers, thereby enhancing the fairness and objectivity of the decision. The following formula is required:

$$\hat{x}_i=\frac{x_i-\min\left(E_i\right)}{\max\left(E_i\right)-\min\left(E_i\right)}$$

However, the multi-attribute decision-making method also has the following shortcomings: it has a higher requirement for decision data, especially when involving numerous decision factors, statistical analysis and data preprocessing work are required. Different algorithms may cause errors or biases during the specific operation process, requiring appropriate correction. The multi-attribute decision-making method itself may involve some compromise and trade-off issues, so the result may have certain uncertainty.

4. Unmanned Reconnaissance Equipment's Applications in Various Fields

The application of unmanned reconnaissance equipment in the military field is mainly reflected in the reconnaissance field, including battlefield reconnaissance, surveillance, and target indication. In the field of battlefield reconnaissance, unmanned reconnaissance equipment is mainly used for battlefield monitoring, target indication, and target recognition due to its all-weather, wide-ranging, and high-efficiency characteristics, and therefore it is widely used in the military field. In the field of surveillance and target indication, unmanned reconnaissance equipment can replace human monitoring and target indication 24 hours a day, such as battlefield monitoring, maritime patrol, aerial surveillance, and electromagnetic signal detection. In the field of target recognition, unmanned reconnaissance equipment can replace humans in identifying and classifying ground and aerial targets, such as target identification and threat classification. Unmanned reconnaissance equipment is widely used in the military field, and the following will focus on its applications in different fields.

Battlefield reconnaissance is mainly used for the monitoring of ground or aerial targets, such as battlefield reconnaissance satellites, drones, etc. Due to its all-weather, wide-ranging, and high-efficiency characteristics, it is widely used in battlefield reconnaissance, especially for the monitoring of ground or aerial targets.

Aerial patrol is mainly used for monitoring the airspace, such as aerial surveillance, aerial patrol, and air defense. Due to its low cost and flexible mobility characteristics, it is widely used in airspace monitoring, especially for monitoring low-altitude airspace.

Electromagnetic signal detection is mainly used for monitoring electromagnetic signals, such as radar signal detection, communication signal detection, etc. Due to its low cost and strong concealment characteristics, it is widely used in the field of electromagnetic signal detection.

Maritime patrol is mainly used for monitoring marine areas, such as maritime patrol satellites, unmanned ships, etc.

Other applications: the applications in other fields also include the following aspects:

(1) Drone refueling stations are mainly used to refuel drones, reducing the operating costs of unmanned aerial vehicles. Currently, China's drone refueling stations are mainly located in the southeastern coastal areas.

(2) Rescue robots are mainly used to provide rescue services for disaster-stricken people. Currently, China's rescue robots are mainly distributed in the northeastern region, and their application areas are relatively limited.

(3) Other applications: In other fields, there are also applications such as robot security, medical care, space exploration, etc., with relatively extensive application scope.

The content flow chart of this paper is shown in Figure 1.

5. Conclusion

From the application of unmanned reconnaissance equipment evaluation methods, each method has its strengths and weaknesses. Although the Analytic Hierarchy Process (AHP) has certain flexibility in determining indicator weights, it cannot quantitatively process indicators very well because it relies too much on expert experience. The Fuzzy Comprehensive Evaluation Method comprehensively considers the experiences of different experts, but it has some subjectivity. The Multi-Attribute Decision Method (MADM) considers the mutual influence and relationship among indicators, can avoid the influence of personal experience factors of decision-makers, but a single method cannot rank various indicators very well and needs to be used in conjunction with other methods. In the future, artificial intelligence technology can be combined with unmanned reconnaissance equipment evaluation to further improve the evaluation system of unmanned reconnaissance equipment and improve the credibility of evaluation results.

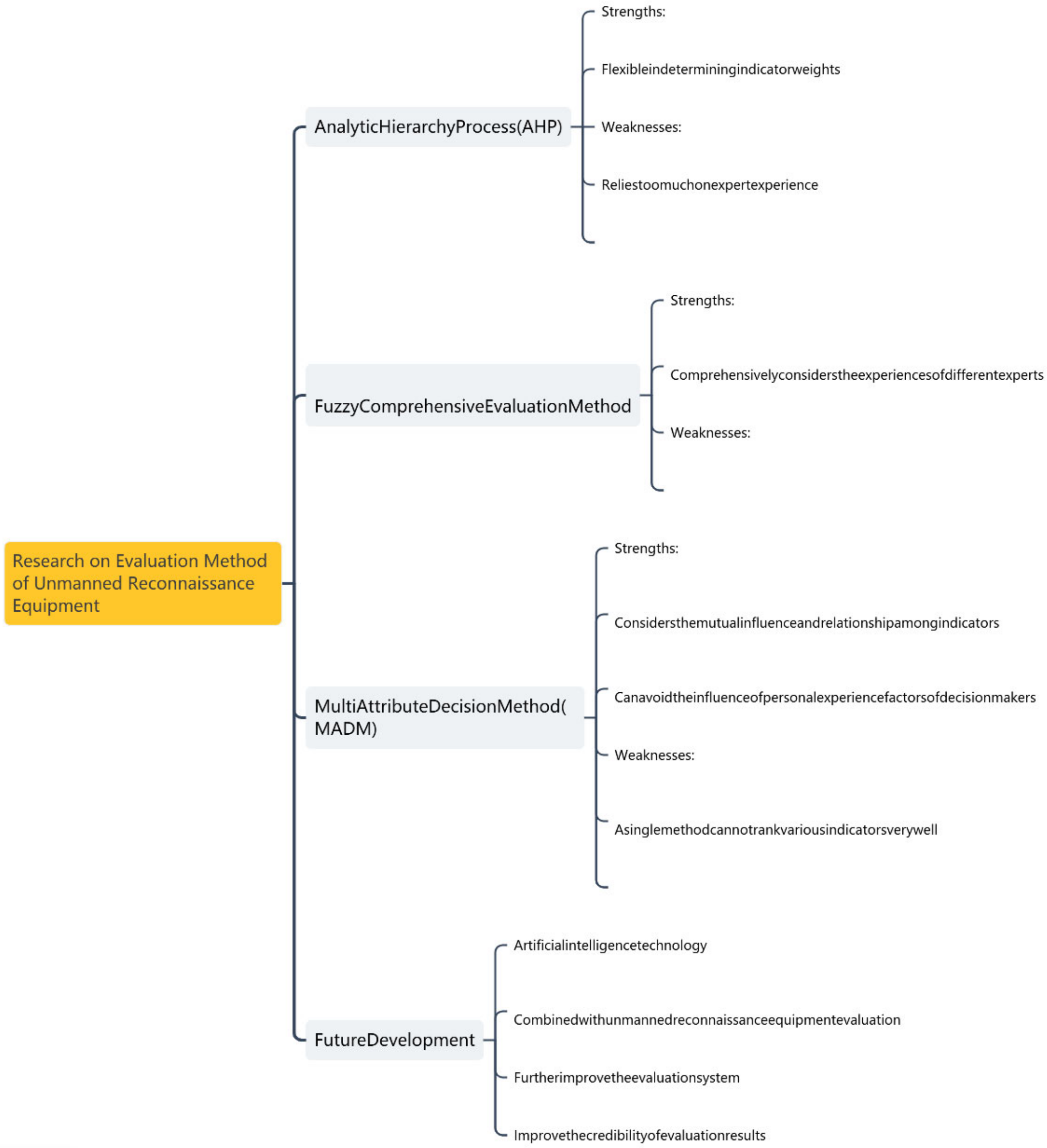

Figure 1. The content flow chart of this paper

References

[1] Che Yanzhuo, Liu Shoubao. Analysis of the Fusion Development of Low-altitude Remote Sensing Technology and Artificial Intelligence Technology for UAVs [J]. China Security, 2021 (4): 34-38.

[2] Cheng Ziyang, Ren Guoquan, Zhang Yin, Jia Ziyong. Current Situation and Trend of Joint Application of Air-Ground Unmanned Equipment [J]. Tactical Missile Technology, 2018 (06): 7-12.

[3] Wang Changlong. Design and Analysis of Propeller Hybrid-driven Amphibious Unmanned Reconnaissance Vehicle [D]. North University of China, 2019.

[4] Hou Jizhan, Zhang Weiguo, Pang Lan, Yang Guang, Zhang Xiajiang, Xu Xiaofeng, Huang Weidong. Development and Key Technology of Small Ground Unmanned Reconnaissance Platform [J]. Applied Optics, 2019, 40 (06): 958-964.

[5] Xue Junjie, Xiao Jiyang, Zhu Jie. Research on the Application Status of US J-type UAV Intelligence Surveillance and Reconnaissance [J]. Flight Dynamics, 2020 (11): 57-62.

[6] Wu Zhaoxiang, Ouyang Quan, Wang Zhisheng, Ma Rui, Cong Yuhua. Research Status and Development of AI-based Regional UAV Reconnaissance Method [J]. Aeronautical Science and Technology, 2020, 31(10): 57-68.

[7] Zhao Xiaohong. Development Status of Foreign Anti-UAV Technology [J]. Light Weapons, 2017 (10): 14-18.

[8] Lu Jing, Cao Chen. Development Status and Future of Unmanned Special Aircraft [J]. Journal of China Academy of Electronics and Information Technology, 2016, 11(03): 223-228.