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ORIGINAL ARTICLE

A Study on the Efficiency Evaluation for Standardization Promotes Green Development of Aviation Equipment

Youwei Meng[1], Tao Zhao[1], Suli Hao [2]*
[1]**College of Management and Economics, Tianjin University, Tianjin 300072, China**
[2]**School of Management, China University of Mining and Technology (Beijing), Beijing 100083, China**
***Corresponding Author: Suli Hao**

Abstract
At present, the global greenhouse gas emissions combustion emits about 51 billion tons to the atmosphere every year. In order to avoid climate disasters caused by greenhouse gases, according to the Paris Agreement, carbon emissions should reach the peak as soon as possible, and net zero emissions should be achieved by 2050. Countries around the world have placed green energy equipment as a top priority, and the process of green aviation is accelerating. Green development of aviation equipment has become a hotspot. Standardization is the key to leading the green aviation industry, improving equipment quality, and reducing equipment costs. Therefore, improving the efficiency of standardization in aviation equipment has become a hot topic in the research of green aviation. Taking the "dual carbon" goal as the back-ground, the system engineering methods have been used to analyze the efficiency mechanism and action path of standardization in promoting green development of aviation equipment. Based on the path of standardization efficiency generation, an evaluation index system of standardization promotes green development of aviation equipment is con-structed. And then the structural equation, network hierarchy analysis method, standard entropy and other methods are integrated to construct the SEM-ANP-NE evaluation model. To validate the proposed model, the A-type helicopter is selected as a case for discussion. This work mainly reveals the mechanism of standardization that promotes green development of aviation equipment, analyzes the key elements affecting standardization effectiveness, and provides reference for improving the efficiency of promoting green development of aviation equipment.
Keywords: Green aviation; Green development of aviation equipment; Standardization effectiveness; SEM-ANP-NE evaluation model

Introduction

International aviation related organizations are committed to promoting aviation carbon emissions reduction, and the aircraft carbon emissions are becoming increasingly strict. In 2016, the International Civil Aviation Organization (ICAO) established the implementation framework of the "International Aviation Carbon Offset and Emission Reduction Mechanism" (CORSIA), with the aim of achieving carbon peak by 2035 and carbon neutrality by 2050[1]. In 2021, the Air Transport Action Group (ATAG) issued a statement promising that global civil aviation transportation will achieve a net zero carbon emissions target by 2050[2]. In 2020, China officially proposed the dual carbon strategy goal (The goal vision of "carbon peaking" and "carbon neutrality", abbreviated as the "dual carbon" strategic goal) [3], with an expected proportion of non-fossil energy consumption reaching 25% by 2030, striving to achieve the carbon peak strategy goal. By 2060, we will comprehensively establish a clean, low-carbon, and efficient energy system, striving to achieve the strategic goal of carbon neutrality[4]. With the rapid development of the economy, the aviation industry accounts for an increasing proportion of China's total carbon emissions. The green development of aviation equipment is an inevitable choice in response to the requirements of the national dual carbon strategy and to achieve efficient and sustainable development of the aviation industry.

Countries around the world have placed green energy equipment as a top priority, and the process of green aviation[5-6] and green aerospace[7-8] is accelerating, and green aviation equipment has become a development hotspot. Standards can effectively promote the efficiency of green development of aviation equipment through their leading and normative roles. Standardization is mainly the activity of giving solutions to applied problems in the fields of science, technology, and economy, with the aim of obtaining the best order [9]. The research on the role and effectiveness of standardization mainly includes two aspects. On the one hand, the relationship be-tween standardization and factors related to economic development is verified by empirical methods from the perspective of standardization results. On the other hand, the role of standardization is theoretically elaborated from the basic principles and attributes of standardization.

In terms of empirical studies, many scholars have mainly studied the effects of standardization on total factor productivity, R&D [10], labor productivity [11], and eco-nomic output [12]. The empirical results show that there is a significant positive relationship between standardization and the above factors. Jiang et al. [13] investigated the mediating effect played by technical standard setting in the impact of collaborative R&D networks on innovation performance of firms and verified the mediating role of standardization. Scholars in China have studied the effects of standardization on the contribution of GDP [14], R&D intensity [15], the contribution of economic growth and regional variability [16], and corporate innovation [17-18]. The results of the study indicate that standardization has a significant contribution to the above factors. In terms of green innovation, Hao et al. [19] studied the impact of standardization on the high-quality development of the new energy vehicle industry. The results show that standardization has a significant contribution to the high-quality development of both the electronic communication industry and the new energy automobile industry.

In the aspect of theoretical analysis, researchers mainly study the mechanism of standardization from the perspective of the economic function of standardization. Rosen et al. [20] proposed that standardization can accelerate the diffusion of technological products, reduce the risk of market entry, reduce the cost of research and development, and increase competitiveness in the international market. Li [21] proposed that standardization is a necessary condition for modern mass production, and is the basis for implementing scientific management and modern management; standardization is conducive to consolidating and developing specialized collaborative production, improving product quality, developing product varieties, eliminating waste, and saving life and materialized labor. Mai [22] analyzed the nature, function, value, and benefit of standards, and analyzed the function of standardization from the perspectives of generalization, serialization, and combination. In addition, scholars have analyzed the function and mechanism of standardization on enterprise management coordination [23], engineering project management [24], enterprise innovation [25-26], highway standardization management [27], logistics enterprise cost and service quality [28], and intellectual property rights integration [29-30], which explores the role of standardization from a theoretical perspective.

With the development of aviation equipment in China, the standardization of aviation equipment mainly has the following four changes. First, it gradually developed from the standardization of graphic symbols of screw nuts to the standardization of the system specification of product performance. Second, it gradually developed from the standardization of process technology to the standardization of technology in design, testing, manufacturing, and safelyuse. Third, it developed from the traditional single standardization to comprehensive standardization. Fourth, it is developed from the design of a simple standardization review to the whole process. With the wide recognition of the supporting role of standardization in scientific research and production of aviation equipment, many research and production units enhance the standardization of aviation equipment to a strategic height, which effectively guides the scientific research and production of equipment. Current research on the standardization of aviation equipment focuses on the establishment of a standardized work system [31], the characteristics of standardized work for aviation equipment [32], the significance of standardized work for aviation equipment [33], and the optimization of standardized management of aviation equipment [34-35].

In the early 1920s, the US Department of Defense adopted the factor analysis method to evaluate the effectiveness of standardization complexes such as mechanical joint standardization, army battery standardization, and submarine standardization. In recent years, in order to enhance standardization effectiveness, the effectiveness evaluation of standardization in aviation equipment has become one of the hot spots. Hu et al. established a standardization work item system and benefit index system for complex product development projects [36]. Geng et al. proposed a maturity model definition that can be used for the evaluation of standardization in type engineering[37]. Du et al. analyzed the standardization activities in the "V" model from the perspective of system engineering[38]. Hu et al. established a standardization effectiveness evaluation index system from the results of model standardization role effective-ness in terms of cost effectiveness, cycle effectiveness, and quality effectiveness to evaluate the model standardization effectiveness[39].

From the above analysis, the literature has carried out some research on green development of aviation equipment, standardization of aviation equipment, and the standardization function, and achieved fruitful results, but there are still some problems in the research. First, the end-to-end research on the role of standardization has been largely mature. However, the path of the role of standardization in these studies is seen as a black box, elaborating the effects of standardization from a theoretical perspective. Therefore, the mechanisms and paths of the role of standardization need to be further explored. Second, scholars have explored evaluation indicators for the green development of aviation equipment, but how to effectively promote the green development of aviation equipment hasn’t been researched, especially through standardization. Third, the standardized efficiency evaluation index system has been established to evaluate the efficiency of standardization, but the efficiency evaluation indicators and models for promoting green development of aviation equipment through standardization have not yet been studied. Therefore, this study reveals the mechanism, constructs an indicator system and evaluation model, and proposes specific suggestions for standardization promoting the green development of aviation equipment.

2. The mechanism of standardization promoting green development of aviation equipment

2.1. Analysis of the attribute space and role of aviation equipment standards

2.1.1. Standard attribute space of aviation equipment

The design, manufacturing, and use of aviation equipment is a complex system including multiple disciplines and fields. Therefore, the standard system of aviation equipment is also a complex system. Hall's three-dimensional structure model is adopted, which includes three dimensions: object dimension, nature dimension, and activity dimension. Combined with the practice of standardization of aviation equipment, a three-dimensional structure model of aviation equipment is constructed, and the model is shown in Figure 1

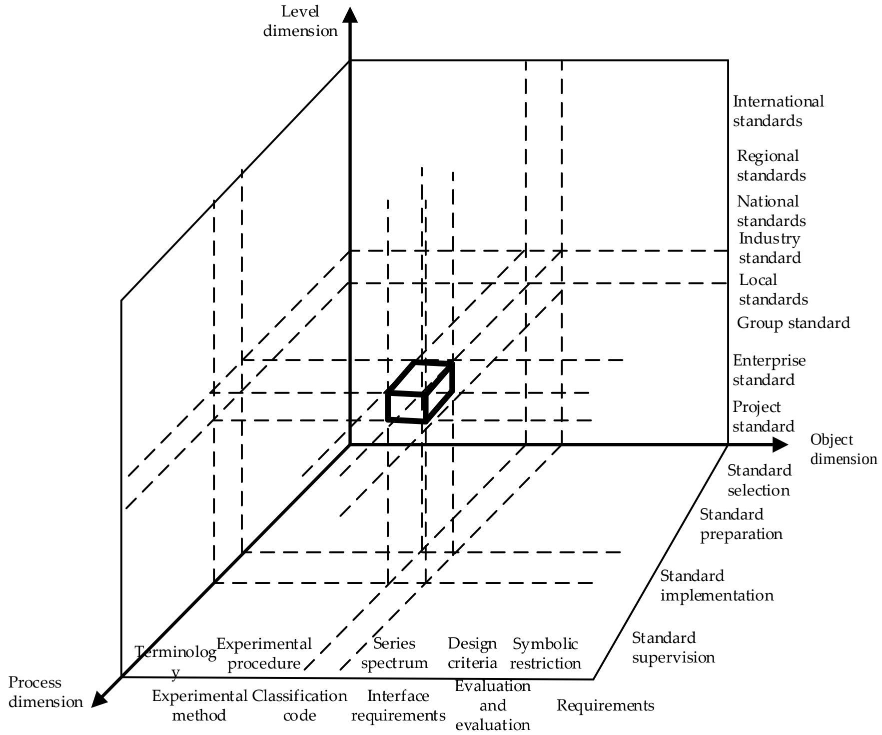

Figure 1. Standard attribute space for aviation equipment.

As can be seen from Figure 1, the three dimensions of the attribute space of the standard system for aviation equipment contain process dimension, level dimension, and object dimension. The process dimension contains standard selection, standard preparation, standard implementation, and standard supervision. The level dimension includes international standards, regional standards, national standards, industry standards, local standards, group standards, enterprise standards, and project standards. Based on the characteristics of the aviation equipment, the object dimension includes terminology standards, test method standards, test procedure class standards, classification code standards, series type spectrum standards, interface requirements standards, design criteria standards, evaluation and assessment standards, symbol class standards, limit value standards, and requirement standards. In the standard attribute space of aviation equipment, any specific standard can find its position in the standard three-dimensional space. The attribute space dynamically reflects the green level of aviation equipment, which can be reflected by the movement of the standard's position in the attribute space.

2.1.2. The Role of standardization Promoting Green Development of Aviation Equipment

Standards have consistency, inertia, reproducibility, and circulation. The main roles of standards include the role of threshold, specification, unification, replication, simplification, interoperability, connection, accumulation, leadership, promotion, arbitration, etc. Tineke M et al. proposed that standards can reduce diversity, improve market transparency and compatibility, and increase the interoperability of information and communication technology products [40]. Then scholars have further expanded the value connotation of standardization, believing that the value of standardization is reflected in preventing information asymmetry, stimulating technological innovation, creating economies of scale, and allowing network externalities. The process of green development of aviation equipment includes green design, green production, and green use. Standardization will also reflect its value in preventing information asymmetry, leading the application and innovation of green development technology, creating economies of scale, and allowing network externalities. And their specific functions are shown in Figure 2.

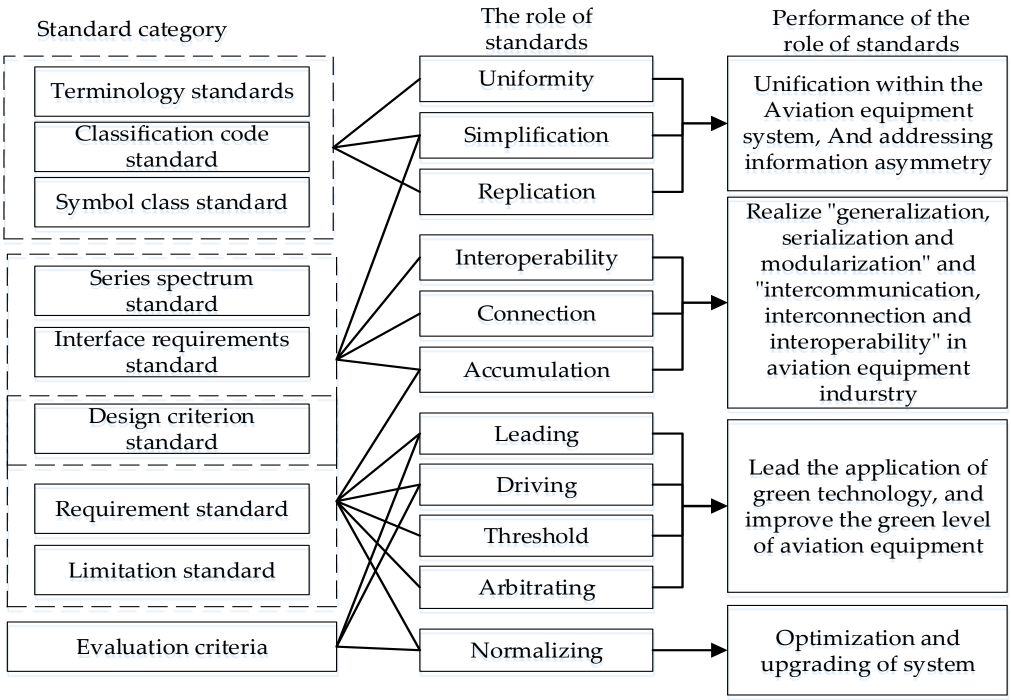

Figure 2. Analysis diagram of standardization function.

2.2. The Path of Standardization Promoting Green Development of Aviation Equipment

Based on the analysis of the role of various standards, this section further explores the path of standardization in promoting the green development of aviation equipment. The specific path contains standardization purpose, standardization degree, standardization value, and overall efficiency of standardization.

2.2.1. The Standardization Degree of Green Development of Aviation Equipment

The degree of standardization is the implementation of standardization. Combining the characteristics of aviation equipment and drawing on the expression of the degree of standardization by Mai [21], the level of standardization of 19 events is selected to measure the degree of standardization of green development of aviation equipment. These 19 events include standardization rate of technical status documents, standardization rate of core business processes, standardization rate of job operations, standardization rate of major standards, standardization rate of general standards, nternational green standard adoption rate, domestic green standard adoption rate, and green technology standardization rate, the "three-oriented" rate of products, "three-oriented" rate of tooling, rate of green process standardization, "three mutual" standardization rate, green parts standardization coefficient, green material standardization coefficient, software interface standardization rate, software component standardization rate, inheritance rate, interchangeability rate, standard conversion enhancement rate.

2.2.2. Factors Influencing Standardization to Promote Green Development of Aviation Equipment

Standardization promotes green technology innovationThe improvement of standardization level of international energy saving and emission reduction standards, energy saving and emission reduction technology adoption, advanced technology standardization, and standard transformation and upgrading will improve the green level of aviation equipment and lay the foundation for achieving energy conservation and emission reduction of aviation equipment.

• Standardization helps optimize the entire process of green development of aviation equipment

Standardization of technical status documents can solidify and control technical status, determine the quality control baseline, and improve the level of equipment quality. It can also carry out extensive cooperation. The improvement of core business process standardization rate and post operation standardization rate is helpful to ensure compliance and reduce risks. In addition, ensuring quality, reducing risks, and strengthening cooperation are all manifestations of improving the efficiency of management.

- Standardization helps to improve the green level of equipment and achieve green design
- By forming effective standards and implementing them in the field of aviation equipment design, design defects can be effectively reduced, technical risks can be controlled, design efficiency can be improved, design costs can be reduced, design cycles can be shortened, and the green level of aviation equipment can be improved.Standardization helps promote the application of green materials and achieve green production

Standardization of green parts, standardization of green materials, "three orientations" of tooling, standardization rate of green processes, "three orientations" of products, standardization of processes, and other events help increase green level of aviation equipment. On the one hand, it promotes the scale effect of aviation equipment production, on the other hand, it can improve the green level in the aviation equipment production process, achieving green production. Standardization helps improve green maintenance and achieve green use

Standardization of major standards, interchangeability rate, "three mutual" standardization, and other events can reduce training times, reduce maintenance materials and labor costs, reduce multi-variety inventory, improve the rapid support capability of aviation equipment in use.

To sum up, the specific path of standardization to improve the development efficiency of green development of aviation equipment is shown in Figure 3.

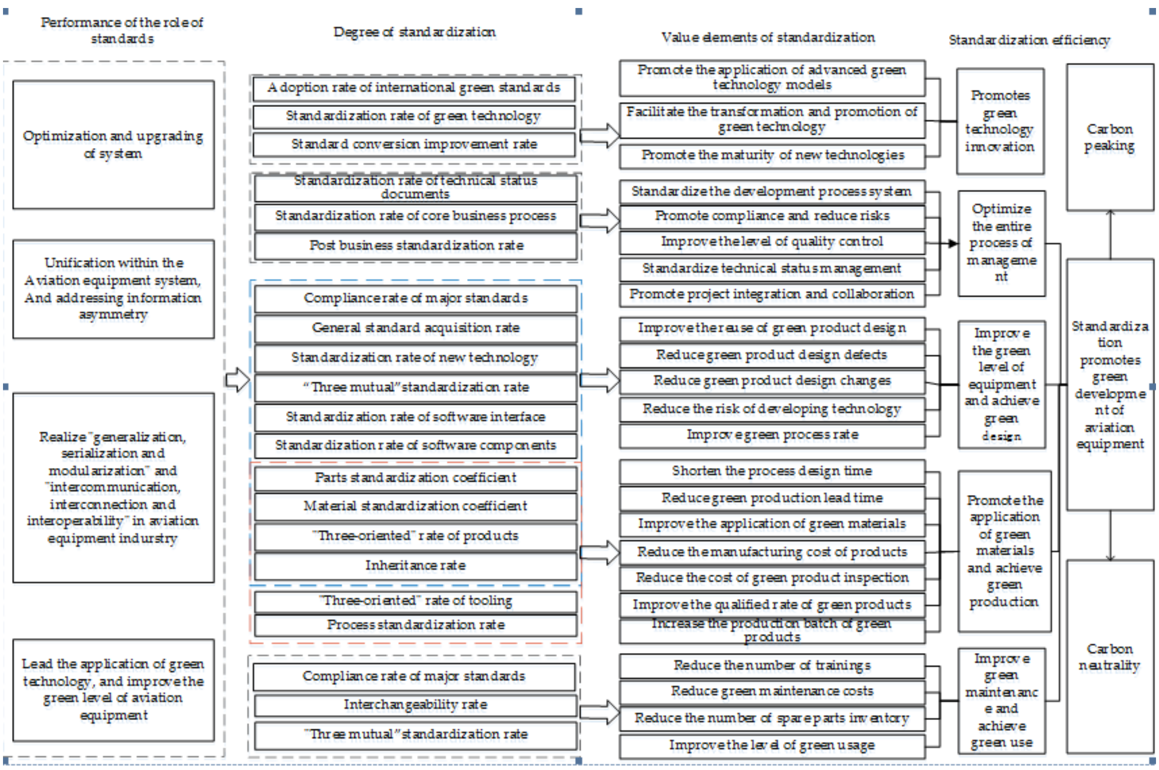

Figure 3. Role path of standardization promotes green development of aviation equipment

3. Design of Standardization Effectiveness Evaluation Index System for Aviation Equipment Green Development

3.1. Principles for Constructing Index System

Standardization effectiveness analysis of aviation equipment is a relatively complex system with multi-level and multi-dimensional characteristics. To build an index system for such a complex system, certain basic principles should be followed instead of simply piling up all its related indicators together [27]. The following is an introduction to the principles of constructing the index system.

3.1.1. Principle of Purpose

The purpose of constructing the efficiency analysis index system based on green development of aviation equipment standardization is to determine the system elements from each system, and to find out the key elements affecting the Standardization effectiveness of aviation equipment. On this basis, a suitable structural model is built using a suitable method. According to the results of the model, the path to improve the Standardization effectiveness is analyzed, the ideas and methods to improve the standardization effectiveness are sought, and the actual effectiveness of each system is continuously improved. The process of constructing the efficiency analysis index system based on the standardization of green development of aviation equipment, it must be carried out closely around the above objectives.

3.1.2. Systematic Principle

The construction of standardization index system for green development of aviation equipment is a complex system, which has the characteristics of multi-level and multi-dimension. When constructing the index system, it should be based on the system thought, follow the gradual refinement from the whole to the parts and the gradual expansion from inside to outside, so as to clarify the structure and relationship of the index system and fully consider the integrity and logical norms of the system.

3.1.3. Principle of Comprehensiveness

The principle of comprehensiveness is to further consider the comprehensiveness of the index system on the basis of the principle of systematicity, so that the constructed index system can reflect the characteristics of each system index of standardization of green development of aviation equipment as comprehensively as possible and can fully consider all aspects that affect the effectiveness of standardization of aviation equipment, avoiding the omission of key issues and important parts.

3.1.4. Principle of Group State

Because the status of each element in the standardization index system for green development of aviation equipment is related, the group principle should be adhered to in the actual design process, and each system should be considered as a whole system. Therefore, in the process of constructing the standardization index system, it should be ensured that the efficiency of each system measured by the index is a group state and has a certain level.

3.1.5. Principle of Objectivity

The standardization index should accurately reflect all aspects and connotations involved in each system management element of standardization of green development of aviation equipment, and the index should be concise and to the point, and its definition and boundary should be clear. Each index should be independent. In order to avoid the influence of subjective factors, the selection of indicators should be determined through discussion and consultation as much as possible.

3.1.6. Principles of Scientific, Feasibility and Comparability

The construction of index system should be based on scientific and reasonable re-flection of standardized efficiency analysis of green development of aviation equipment, control the number of indexes, adjust the degree of simplification, and ensure that authoritative data can be obtained through effective channels in terms of the index value. In addition, when constructing the index system, we should take into account both the comprehensive assessment and comparison between each system based on the analysis of the standardized effectiveness, while also considering the need for comparison between systems, digging deeper into the specific factors affecting the standardized effectiveness in each system, and proposing targeted solutions or regulatory measures.

It should be noted that in the process of following the above principles to construct the standardized effectiveness analysis index system for green development of aviation equipment, the problem of contradiction and conflict in the principles of index system construction will appear. For example, the principle of comprehensiveness re-quires that the indicators can cover the purpose of the study, the number of indicators is often higher, and more indicators may cause conflicts with the principles of feasibility and objectivity. Therefore, in the actual construction process, specific analysis should be made for specific problems, and experts in the same field should weigh and judge.

3.2. Thoughts on the Construction of Index System

Combined with literature research and expert investigation, following the principle of index system construction, this article preliminarily constructs the evaluation index system of Standardization effectiveness for green development of aviation equipment, screens and optimizes the indexes, and finally determines the index system on the basis of analyzing the connotation of Standardization effectiveness and the purpose of constructing index system, according to the results obtained from the third part of standardization path analysis of aviation equipment engineering. The idea of constructing the index system is shown in Figure 4.

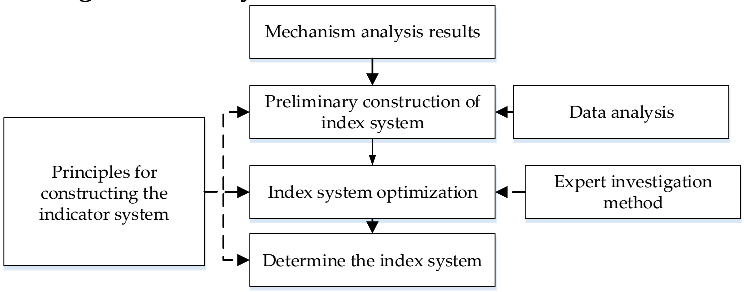

Figure 4. Thoughts on the construction of index system

3.3. Preliminary Construction of Index System

Based on the influencing factors of Standardization effectiveness analysis of green development of aviation equipment, the second-level evaluation indexes of Standardization effectiveness of aviation equipment engineering are constructed from five aspects, such as optimizing engineering management process, improving equipment development efficiency, creating production scale effect, helping us support efficiency and promoting technological progress of the society, and 26 third-level indexes are designed. See Figure 5 below for details.

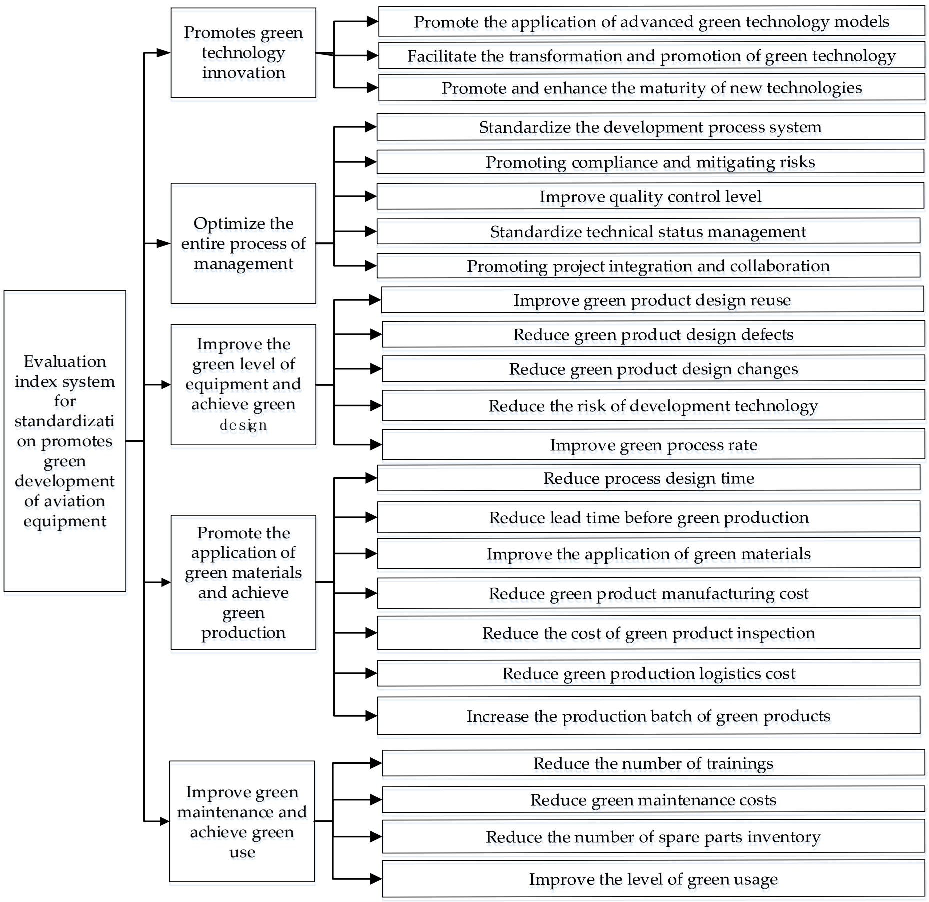

Figure 5. Indicator architecture framework

3.4. Indicator Optimization and Indicator Description

A questionnaire study was conducted on the standardized effectiveness evaluation index system in the form of a 5-point Likert scale (refer to Attachment 1 for the questionnaire), with 142 questionnaires distributed to aviation equipment design organizations, manufacturing organizations, user organizations, and universities and 127 questionnaires returned to verify the scientificity of indicators and the relationship between indicators. The 122 valid questionnaires collected were statistically analyzed according to the departments to which they belonged. Among them, there were 46 questionnaires from the design department, accounting for 38%. There were 40 questionnaires from the manufacturing department, accounting for 33%. There were 23 questionnaires from the standardization department, accounting for 19%. There were 9 questionnaires from the management department, accounting for 7%. There were 4 questionnaires from the inspection department and others, accounting for 3%. From the sorting point of view, the departments to which the samples belong are distributed reasonably and have strong representativeness. The distribution is shown in Figure 6.

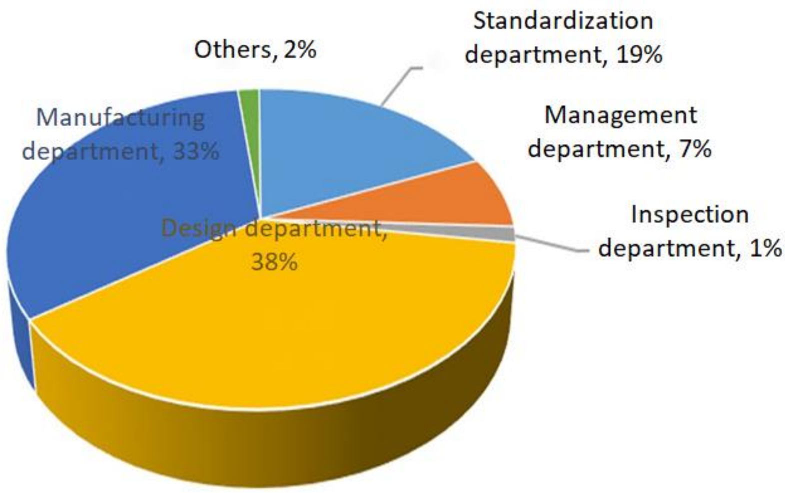

Figure 6 Distribution chart of survey departments

3.4.1. Data Statistics and Processing

In terms of statistics and processing of data, the article mainly used fuzzy performance theory and correlation analysis methods to process the research data. The results show that the minimum value of the performance evaluation index of standardization effectiveness of aviation equipment is 3.39, the maximum value is 4.647, and there is no supplementary index in other open-ended problems. A performance evaluation value less than 3.5 is considered to be a less contributing indicator. Therefore, based on the calculation results of performance value, two indexes, namely, im-proving the qualified rate of products and improving the production batch of sup-porting finished products, are eliminated.

On the basis of performance score calculation, factor analysis and correlation analysis are applied to analyze the correlation and contribution of each index. The results show that the correlation between shortening process design time and reducing production preparation time is 0.78, and the correlation coefficient is greater than 0.5. Therefore, these two indexes are combined, and the combined index name shortens the time of pre-production preparation.

3.4.2. Optimization of Index System

Based on the above analysis results, the evaluation indexes of standardization effectiveness include five second-level indexes and 22 third-level indexes. The index system and index description are shown in Table 1.

Table 1. Weight of standardized benefit evaluation index for green development of aviation equipment engineering.

First-class index	Weight	Secondary index	Local Weight	Global Weight

First-class index	Weight	Secondary index	Local Weight	Global Weight
Promotes green technology innovation R1	0.102	Promote the application of advanced green technology R11	0.527	0.053816
		Facilitate the transformation and promotion of green technology R12	0.231	0.023555
		Promote and enhance the maturity of new technologies R13	0.242	0.024753
Optimize the entire process of managementR2	0.122	Standardize the development process system R11	0.045	0.005529
		Promoting compliance and mitigating risks R12	0.275	0.033673
		Improve quality control level R13	0.149	0.018212
		Standardize technical status management R14	0.498	0.060929
		Promoting project integration and collaboration R15	0.033	0.004024
Improve the green level of equipment and achieve green design R3	0.525	Improve green product design reuse R21	0.060	0.031536
		Reduce green product design defects R22	0.255	0.134178
		Reduce green product design changes R23	0.223	0.117233
		Reduce the risk of development technology R24	0.240	0.126148
		Improve green process rate R25	0.222	0.116428
Promote the application of green materials and achieve green production R4	0.209	Reduce lead time before production R31	0.163	0.034118
		Improve the application of green materials R32	0.174	0.036289
		Reduce green product manufacturing cost R33	0.193	0.040247
		Reduce the cost of green product inspection R34	0.168	0.035161
		Increase the production batch of green products R35	0.302	0.063203
Improve green maintenance and achieve green use R5	0.041	Reduce the number of trainings R41	0.394	0.016136
		Reduce green maintenance costs R42	0.192	0.007862
		Reduce the number of spare parts inventory R43	0.163	0.006666
		Improve the level of green usage R44	0.252	0.010303

4. Standardization Effectiveness Evaluation for Green Development of Aviation Equipment

4.1. Modeling Ideas (SEM-ANP-NE)

The standardization effectiveness evaluation for green development of aviation equipment is a relatively complex system analysis, which needs to consider the influencing factors of effectiveness standardization from multiple dimensions. There are multiple levels of systems, and there are significant interrelationships among system elements. In order to better achieve the multi-dimension and multi-level standardization effectiveness analysis, consider the relationship between influencing factors and the uncertainty of the evaluation level language concept, and improve the accuracy of the effectiveness evaluation, the relevant personnel should consider the integrated method of "SEM-ANP-NE" when choosing the method of con-structing the standardized effectiveness evaluation model. In short, the network analytic hierarchy process (ANP) is used. According to the PLS-SEM analysis results of the relationship among various factors, the weight of each index is calculated, and the membership degree of each index is calculated by the algorithm of normalized entropy. Finally, the standardization effectiveness is comprehensively calculated. The following specifies the research ideas, as shown in Figure 7.

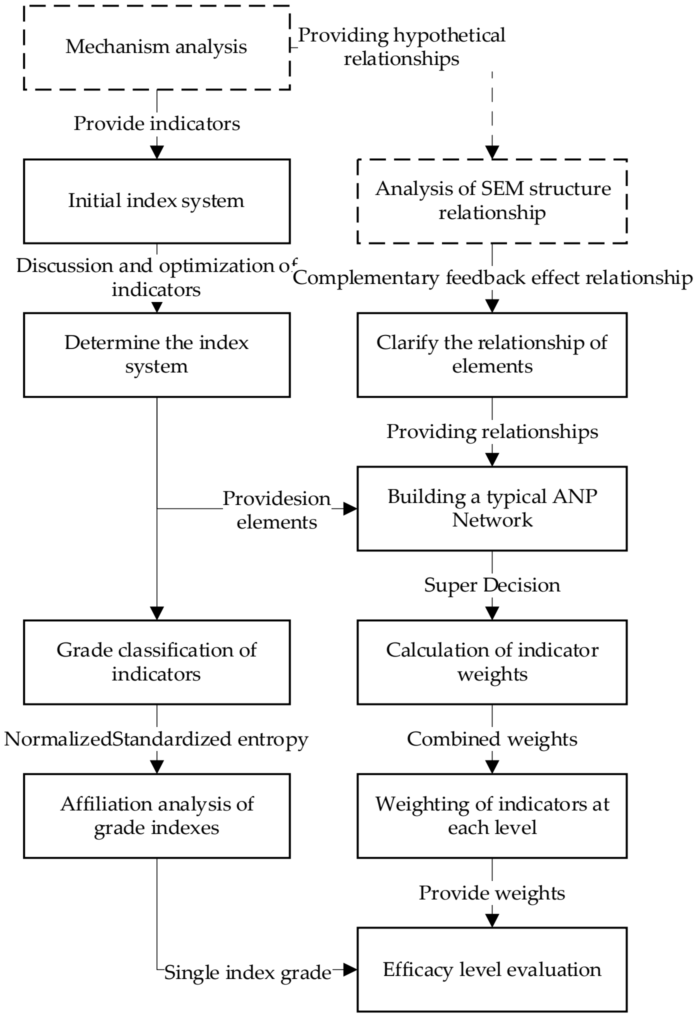

Figure 7 Research ideas on the construction of the standardization benefit evaluation model for green development of aviation equipment.

The first step is to determine the index weight. Firstly, according to the results of SEM structural relationship analysis, the relationship between each index is defined, and the ANP typical network is constructed. Then, according to the specific process of ANP index weight calculation, the local weight and global weight of each index are obtained.

The second step is to classify grades of individual indexes. For the constructed index system, in accordance with the standardization rate of green development of aviation equipment and its metrological analysis, the individual index grade is determined, and the classified results are discussed with experts to optimize the grade intervals.

The third step is to analyze the membership degree of each index grade. The index is divided into qualitative index and quantitative index. The quantitative index uses the normalized entropy method to calculate the benefit membership degree of each index, and the qualitative index determines the grade membership degree according to the way of expert evaluation.

The fourth step is the effectiveness evaluation grade. According to the weight and the grade membership degree of each index, the comprehensive grade membership degree is calculated by multiplying. Then, according to the principle of maximum membership degree or weighted membership degree, the evaluation grade of standardization benefit of green development of aviation equipment in each dimension is measured.

4.2. Determination of Index Weights Based on the Network Analytic Hierarchy Process (ANP)

The network analytic hierarchy process is a decision analysis method that fully considers the interaction between various factors and adjacent levels, constructs a comparison matrix between elements through direct dominance and indirect dominance, and uses "super matrix" to analyze various factors so as to obtain local and global weights. This method is an extension of the analytic hierarchy process and can deal with the characteristics of interacting factors, gradually becoming an effective method for solving complex decision-making problems.

4.2.1. Relational Structure Assumptions

In this article, the PLS-SEM model is used to analyze the structural relationship of standardization effectiveness evaluation system for green development of aviation equipment. Based on the mechanism analysis of standardization effectiveness, the relationship hypothesis among five indexes is obtained as shown in Figure 8.

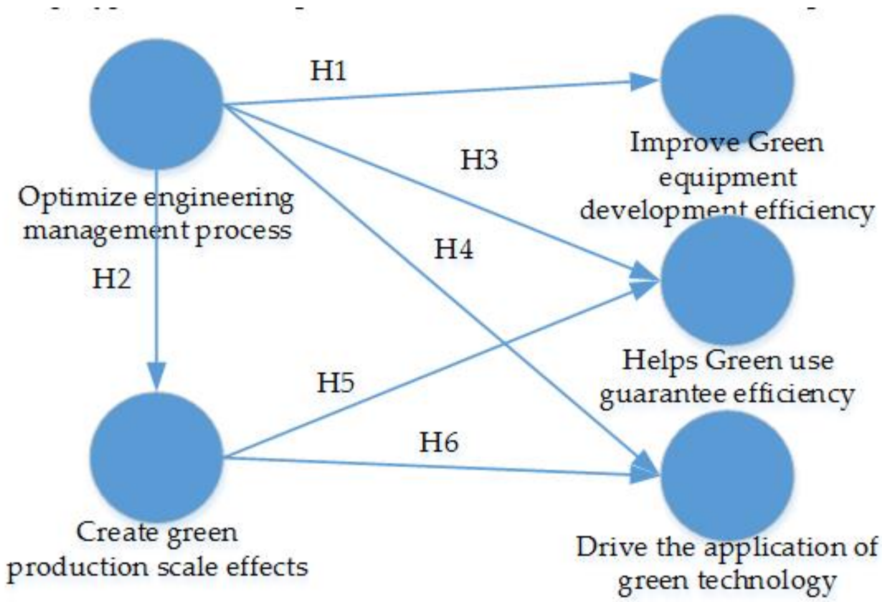

Figure 8. Relationship structure assumptions among indexes.

Based on the relational structure in Figure 8, the following assumptions are given.
H1: Optimizing the entire process of management has a significant positive effect on improving the green level of equipment and achieving green design.
H2: Optimizing the entire process of management has a significant positive effect on promoting the application of green materials and achieving green production.
H3: Optimizing the entire process of management has a significant positive effect on improving green maintenance and achieving green use.
H4: Optimizing the entire process of management has a significant positive effect on promoting green technology innovation.
H5: Promoting the application of green materials and achieving green production has a significant positive effect on improving green maintenance and achieving green use.
H6: Promoting the application of green materials and achieving green production has a significant positive effect on promoting green technology innovation.

4.2.2. Model Validation and Revision

Based on the relationship between standardization effectiveness indexes, combined with the characteristics of structural equation, the constitutive model is selected, the hypothesis is tested by SmartPLS3.0 software, the path coefficient among variables is estimated by PLS and PLS Bootstrapping algorithm, and the significance of the model is verified. The verification results are shown in Figure 9.

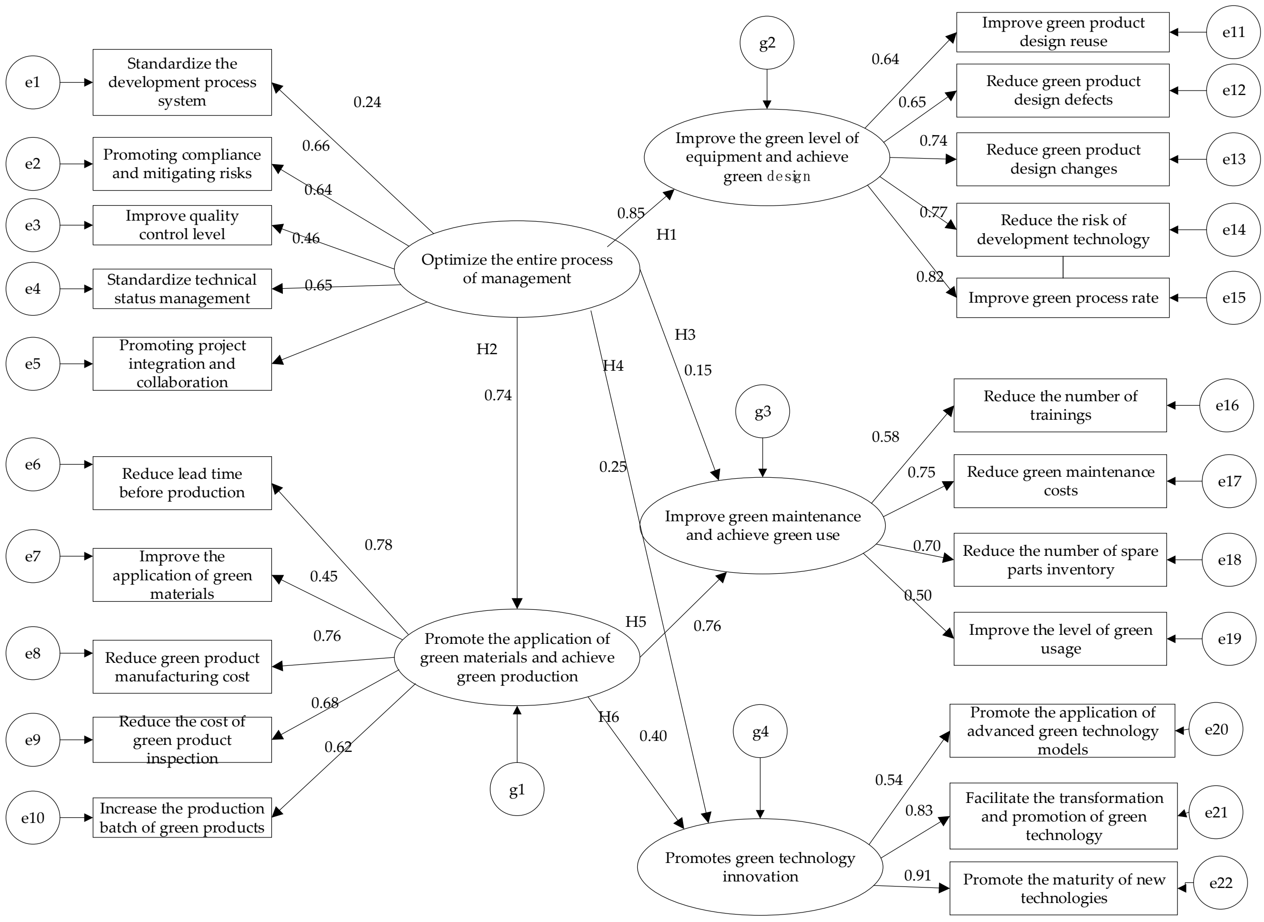

Figure 9. Hypothetical relation model estimation and test results among indexes.

The calculated path coefficients of each hypothetical path relation and their significance test values are shown in Table 2. As can be seen from Table 2, except for H1-3 and H1-4 path relations, other hypothetical path relations are significant at the 5% significance level. The significance test P value of H1-3 and H1-4 path coefficients are greater than 0.1, which fails the significance test. This indicates that there is no significant causal relation between optimizing engineering management, boosting usage and support effectiveness, and promoting socio-technical progress.

Table 2. Hypothetical path relation coefficient and significance test.

Hypothetical path relation	Path coefficient	T value	P value
H1-1 Optimize the entire process of management R2- > -Improve the green level of equipment and achieve green design R3	0.850	5.422	***
H1-2 Optimize the entire process of management R2-> Promote the application of green materials and achieve green production R4	0.740	5.842	***
H1-3 Optimize the entire process of management R2-> Improve green maintenance and achieve green use R5	0.150	0.988	0.323
H1-4 Optimize the entire process of management R2-> Promote green technology innovation R1	0.250	1.509	0.131
H1-5 Promote the application of green materials and achieve green production R3-> Improve green maintenance and achieve green use R5	0.760	4.182	***

H1-6 Promote the application of green materials and achieve green production R4-> Promote green technology innovation R1	0.400		2.403	0.016

4.2.3. Index weight calculation based on the ANP

According to the evaluation results of standardization effectiveness for green development of aviation equipment engineering by PLS-SEM model, in order to further determine the interdependence of the indexes of standardization effectiveness evaluation, the relevant personnel invited seven experienced experts in the industry field to score and determine the interdependence among relevant evaluation indexes. On this basis, the standardization effectiveness evaluation is taken as the control layer, and promotes green technology innovation, optimizes the entire process of management, the green level of equipment and achieves green design, promotes the application of green materials and achieve green production, improves green maintenance and achieves green use are taken as the network layer. The ANP model was constructed using Super Decision software and the results are shown in Figure 10.

Figure 10. ANP model for standardization benefit evaluation of green development of aviation equipment.

The index weights are determined based on the network analytic hierarchy process (ANP). Suppose that the control layer in ANP model is N and there are B_i network layers, where B_i has elements $B_{ij}(i=1,2,\cdots n)$, and the weight of each index is calculated as follows.

Calculate the normalized eigenvectors of the judgment matrix for each B_{ij}. In this step, the judgment matrix takes B_i as a criterion and B_{ij} as the sub-criterion; the characteristic root method is used to calculate $w_{ij}^T(i=1,2,\cdots n)$.

The standardization of process development system is considered as a criterion, the influence of improving product design reuse, reducing product design defects, reducing product design changes, reducing the risk of technology development and reducing test and evaluation costs on the standardization of process development system is compared in relative importance, and the weight vector is calculated. As shown in Table 3, the consistency test result is 0.0706, which is less than 0.1 and acceptable.

Table 3. Relative importance and weight vector under the green level of equipment and achieve green design.

Improve green equipment development efficiency R3	**Improve green product design reuse R31**	**Reduce green product design defects R32**	**Reduce green product design changes R33**	**Reduce the risk of technology development R34**	**Improve green process rate R35**	**Weight vector**
Improve green product design reuse R31	1	1/4	1/5	1/4	1/6	0.044777
Reduce green product design defects R32	4	1	1/4	1/4	1/5	0.085723
Reduce green product design changes R33	5	4	1	1/2	1/4	0.184497
Reduce the risk of technology development R34	4	4	2	1	1	0.292069
Improve green process rate R35	6	5	4	1	1	0.392935
CR=0.0706						

Relevant personnel repeat the above steps to obtain the weight vectors of improving green product design reuse, reducing green product design defects, reducing green product design changes, reducing the risk of technology development and improving green process rate By sequentially combining the five weight vectors in table 3, the judgment matrix can been obtained, which is a sub-block of the supermatrix W.

$$w_{21} = \begin{bmatrix} 0.045 & 0.000 & 0.110 & 0.068 & 0.000 \\ 0.086 & 0.268 & 0.174 & 0.199 & 0.000 \\ 0.184 & 0.117 & 0.399 & 0.000 & 0.000 \\ 0.292 & 0.000 & 0.316 & 0.000 & 0.500 \\ 0.393 & 0.614 & 0.000 & 0.733 & 0.500 \end{bmatrix} \quad W = \begin{bmatrix} w_{11} & w_{12} & w_{13} & w_{14} & w_{15} \\ w_{21} & w_{22} & w_{23} & w_{24} & w_{25} \\ w_{31} & w_{32} & w_{33} & w_{34} & w_{35} \\ w_{41} & w_{42} & w_{43} & w_{44} & w_{45} \\ w_{51} & w_{52} & w_{53} & w_{54} & w_{55} \end{bmatrix}$$

Calculate the unweighted hypermatrix. Relevant personnel repeat the above process, input the pairwise contrast ratio of all secondary indexes into SD software and perform retrograde calculations, and obtain the judgment matrix w_{ij}. And the judgment matrix is formed into an unweighted supermatrix W in a specific order.

$$W = \begin{bmatrix}
0.000 & 0.489 & 0.145 & 0.500 & 0.495 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.078 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.748 & 0.000 & 0.212 & 0.500 & 0.260 & 0.333 & 0.000 & 0.634 & 0.000 & 0.637 & 0.267 & 0.000 & 0.000 & 0.529 & 0.531 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.143 & 0.444 & 0.000 & 0.000 & 0.087 & 0.667 & 0.167 & 0.174 & 0.000 & 0.000 & 0.397 & 0.000 & 0.659 & 0.134 & 0.138 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.067 & 0.594 & 0.000 & 0.158 & 0.000 & 0.833 & 0.192 & 1.000 & 0.258 & 0.258 & 1.000 & 0.156 & 0.268 & 0.256 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.109 & 0.000 & 0.049 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.105 & 0.000 & 0.000 & 0.185 & 0.068 & 0.075 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.045 & 0.000 & 0.110 & 0.068 & 0.000 & 0.000 & 0.000 & 0.100 & 0.104 & 0.063 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.086 & 0.268 & 0.174 & 0.199 & 0.000 & 0.167 & 0.000 & 0.433 & 0.502 & 0.161 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.184 & 0.117 & 0.399 & 0.000 & 0.000 & 0.000 & 0.149 & 0.000 & 0.286 & 0.604 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.292 & 0.000 & 0.316 & 0.000 & 0.500 & 0.000 & 0.474 & 0.466 & 0.000 & 0.173 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.393 & 0.614 & 0.000 & 0.733 & 0.500 & 0.833 & 0.376 & 0.000 & 0.108 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
1.000 & 0.000 & 0.086 & 0.051 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.466 & 0.000 & 0.000 & 1.000 & 0.000 & 0.287 & 0.300 & 0.399 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.614 & 0.265 & 0.288 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 1.000 & 0.000 & 0.000 & 0.140 & 0.122 & 0.000 & 0.167 & 0.000 & 0.000 & 0.061 & 0.113 & 0.000 & 0.000 \\
0.000 & 0.076 & 0.089 & 0.467 & 0.103 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.333 & 0.320 & 0.000 & 0.000 & 0.078 & 0.081 & 0.000 & 0.179 & 0.000 & 0.500 \\
0.000 & 0.131 & 0.211 & 0.140 & 0.188 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.100 & 0.000 & 0.558 & 0.000 & 0.000 & 0.000 & 0.091 & 0.140 & 0.000 & 0.000 & 0.500 \\
0.000 & 0.793 & 0.000 & 0.077 & 0.422 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.433 & 0.528 & 0.000 & 0.000 & 0.833 & 0.635 & 0.528 & 0.399 & 0.709 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.612 & 0.000 & 0.619 & 0.451 & 0.075 & 0.000 & 0.751 & 0.667 & 0.709 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.103 & 0.000 & 0.090 & 0.186 & 0.384 & 0.000 & 0.000 & 0.222 & 0.179 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.213 & 0.000 & 0.235 & 0.293 & 0.086 & 0.000 & 0.178 & 0.000 & 0.113 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.072 & 0.000 & 0.056 & 0.071 & 0.455 & 1.000 & 0.070 & 0.111 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.172 & 0.000 & 0.131 & 0.125 & 0.070 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.131 & 0.500 & 0.143 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.726 & 0.333 & 0.000 & 0.875 & 0.589 & 0.000 & 0.000 & 0.000 & 0.000 & 0.900 & 0.000 & 0.000 & 0.714 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.333 & 0.661 & 0.000 & 0.248 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.661 & 0.000 & 0.143 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.102 & 0.333 & 0.208 & 0.000 & 0.093 & 0.000 & 0.000 & 0.000 & 0.000 & 0.100 & 0.208 & 0.500 & 0.000
\end{bmatrix}$$

The weighted supermatrix $\bar{w}$ is calculated. The eigenvector a_{ij} is normalized by calculating the first-class index. Relevant personnel summarize a_{ij} to obtain a weight matrix A, which is marked as 0 if there is no impact, and $\sum_{i=1}^{5} a_{ij} = 1$. On this basis, the weighted hypermatrix $\bar{W} = A \cdot W = a_{ij} \cdot w_{ij}$ is calculated. The limit matrix of weighted matrix is calculated by power method. The weighted supermatrix is stabilized by the limit relative ranking vector to generate the global and local weight of each element. All the calculated CR results were less than 0.1, and the consistency tests were passed. The calculated weight results of each evaluation index of standardization benefit evaluation for green development of aviation equipment engineering are shown in Table 1.

4.3. Evaluation of Standardization Effectiveness Based on the Normalized Entropy (NE)

Entropy is a concept of thermodynamics, proposed by German physicist Clausius in 1865. Entropy is a physical quantity that describes the state of a system. And it can represent the degree of chaos in a system. Entropy has important applications in fields such as cybernetics, information theory, astrophysics, and life sciences, and it is borrowed and extended to explain or explain certain system states and relationships in one's own discipline. In 2017, MAI Lubo proposed the concept of standardized entropy. Using entropy to measure the standardized state of a system is called standardized entropy. Normalized entropy is a measure of the system status. The object of entropy measure is the system, and there are events in a system. Suppose there exists a system A, and the events in system *A* are combined as $H=\{h_1,h_2,\cdots,h_n\}$.The normalized entropy S of the system status is $S=-\ln(p_1,p_2,\cdots p_n)=\sum_{i=1}^{n}-\ln p_i$, p_i is the occurrence probability of the normalized status of the i_{th} event, or it can be the proportion of the normalized status formation or the degree of normalized status, etc. The numerical range is $0<p_i<100\%$.

In practice, it is not only necessary to measure the probability or degree of normalization of the system, but also the value brought by normalization, or to express the value from the useful normalization input by the system through normalized entropy. With the increase of standardization value, the entropy of the system changes from large to small. For standardization promotes green development of aviation equipment system, this kind of entropy measure is for the standardization value of its components. Normalized entropy is a measure of the degree of value utilization and the degree of value-free utilization for green development of aviation equipment engineering components. If relevant personnel measure the normalized value of the system through normalized entropy, they need to assign normalized value systems to events. The entropy for measuring the standardized value of the system can be expressed as:

$$S_v=-\ln(k_1p_1\cdot k_2p_2\cdots k_np_n)=\sum_{i=1}^{n}-\ln k_ip_i \qquad (1)$$

In Formula (1), S_V is the entropy for measuring the normalized value of a system. Since the value brought by the standardization of different events $\boldsymbol{h_i}$ is different, each event has its own standardized value coefficient. The product of the value coefficient and event occurrence probability is the entropy S_V of the standardized value measure of the system.

4.3.1. Normalized Events

Based on the analysis of standardization effectiveness mechanism for green development of aviation equipment, the standardization events of each index of standardization effectiveness evaluation for green development of aviation equipment are studied by means of expert interview and questionnaire investigation. The specific results are shown in Table 4.

Table 4. Events table of standardization effectiveness for green development of aviation equipment.

Tertiary indexes	Events of indexes
Promote the application of advanced green technology Facilitate the transformation and promotion of green technology Promote and enhance the maturity of new technologies	{Adoption of international green standards, adoption of internal green standards, standardizatione of Energy saving and emission reduction technology technologies,}
Standardize the process development system Promote compliance and reduce risks Improve the quality control level Standardize technical status management Promote project integration and collaboration	{Standardization of technical status documents, core business processes and post operation}
Improve green product design reuse Reduce green product design defects Reduce green product design changes Reduce the risk of technology development Improve green process rate	{Implementation of green standards, adoption of general standards, standardization of green technologies, "three orientations" of products, "three mutual" standardization, green parts standardization, green material standardization, standardization rate of software interfaces, standardization rate of software components, inheritance}

Tertiary indexes	Events of indexes
Reduce the preparation time before production Improve the application of green materials Reduce green product manufacturing costs Reduce the cost of green product inspection Increase the production batch of green products	"Three orientations" of products, "three orientations" of tooling, process standardization, green parts standardization, green material standardization, inheritance
Reduce the number of trainings Reduce green repair and maintenance costs Reduce the inventory number of spare parts Improve the level of green usage Promote the maturity of new technologies	Implementation of major standards, interchangeability, "three mutual" standardization

4.3.2. Standard event value coefficient

The value coefficient of each standardized event is investigated by questionnaire. The distribution and collection of questionnaires can be found in 3.4, and the statistical results are shown in Table 5.

Table 5. Standardization event value coefficient for green development of aviation equipment.

Indexes	Measurement factor	Normalization
Promote the application of advanced green technology	Adoption rate of international green standards	0.528
	Adoption rate of internal green standards	0.148
	Standardized rate of green technologies	0.324
Facilitate the transformation and promotion of green technology	Adoption rate of international green standards	0
	Adoption rate of internal green standards	0
	Standardized rate of green technologies	1
Promote and enhance the maturity of new technologies	Adoption rate of international green standards	0.006
	Adoption rate of internal green standards	0.212
	Standardized rate of green technologies	0.551
Standardize the process development system	Standardization rate of technical status documents	0.238
	Standardized rate of core business processes	0.438
	Post operation standardized rate	0.324
Promote compliance and reduce risks	Standardized rate of technical status documents	0.532
	Standardized rate of core business processes	0.271
	Post operation standardized rate	0.197
Improve the quality control level	Standardized rate of technical status documents	0.19
	Standardized rate of core business processes	0.481
	Post operation standardized rate	0.329
Standardize technical status management	Standardized rate of technical status documents	0.536
	Standardized rate of core business processes	0.237
	Post operation standardized rate	0.227
Promote project integration and collaboration	Standardized rate of technical status documents	0.645
	Standardized rate of core business processes	0.182
	Post operation standardized rate	0.173
Improve green product design reuse	Implementation rate of green standards	0.193
	Adoption rate of general standards	0.151
	Standardized rate of energy saving and emission reduction technology technologies	0.009

Indexes	Measurement factor	Normalization
	"Three orientations" rate of products	0.1
	"Three mutual" standardization rate	0.098
	Green parts standardization coefficient	0.101
	Green material standardization coefficient	0.101
	Standardization rate of software interfaces	0.009
	Standardization rate of software components	0.055
	Inheritance rate	0.183
Reduce green product design defects	Implementation rate of green standards	0.101
	Adoption rate of general standards	0.101
	Standardized rate of green technology technologies	0.102
	"Three orientations" rate of products	0.1
	"Three mutual" standardization rate	0.098
	Green parts standardization coefficient	0.1
	Green material standardization coefficient	0.101
	Standardization rate of software interfaces	0.098
	Standardization rate of software components	0.1
	Inheritance rate	0.099
Reduce green product design changes Reduce product design changes	Implementation rate of green standards	0.103
	Adoption rate of general standards	0.101
	Standardized rate of green technology technologies	0.099
	"Three orientations" rate of products	0.097
	"Three mutual" standardization rate	0.098
	Green parts standardization coefficient	0.102
	Green material standardization coefficient	0.102
	Standardization rate of software interfaces	0.098
	Standardization rate of software components	0.1
	Inheritance rate	0.1
Reduce the risk of technology development	Implementation rate of green standards	0.102
	Adoption rate of general standards	0.103
	Standardized rate of green technology technologies	0.099
	"Three orientations" rate of products	0.099
	"Three mutual" standardization rate	0.098
	Green parts standardization coefficient	0.101
	Green material standardization coefficient	0.101
	Standardization rate of software interfaces	0.097
	Standardization rate of software components	0.099
	Inheritance rate	0.101
Improve green process rate	Implementation rate of green standards	0.102
	Adoption rate of general standards	0.101
	Standardized rate of green technology technologies	0.099
	"Three orientations" rate of products	0.101
	"Three mutual" standardization rate	0.099
	Green parts standardization coefficient	0.104
	Green material standardization coefficient	0.1
	Standardization rate of software interfaces	0.098
	Standardization rate of software components	0.098
	Inheritance rate	0.099
Reduce the preparation time before production	"Three orientations" rate of products	0.165
	"Three orientations" rate of tooling	0.165
	Process standardized rate	0.167

Indexes	Measurement factor	Normalization
	Green parts standardization coefficient	0.166
	Green material standardization coefficient	0.171
	Inheritance rate	0.165
Improve the application of green materials	"Three orientations" rate of products	0.268
	"Three orientations" rate of tooling	0.096
	Process standardized rate	0.05
	Green parts standardization coefficient	0.217
	Green material standardization coefficient	0.201
	Inheritance rate	0.168
Reduce green product manufacturing costs	"Three orientations" rate of products	0.207
	"Three orientations" rate of tooling	0.101
	Process standardized rate	0.1
	Green parts standardization coefficient	0.215
	Green material standardization coefficient	0.209
	Inheritance rate	0.168
Reduce the cost of green product inspection	"Three orientations" rate of products	0.267
	"Three orientations" rate of tooling	0.101
	Process standardized rate	0.009
	Green parts standardization coefficient	0.218
	Green material standardization coefficient	0.239
	Inheritance rate	0.166
Increase the production batch of green products	"Three orientations" rate of products	0.259
	"Three orientations" rate of tooling	0.009
	Process standardized rate	0.004
	Green parts standardization coefficient	0.287
	Green material standardization coefficient	0.275
	Inheritance rate	0.166
Reduce the number of trainings	Implementation rate of green standards	0.336
	Interchangeability rate	0.331
	"Three mutual" standardization rate	0.333
Reduce green repair and maintenance costs	Implementation rate of green standards	0.334
	Interchangeability rate	0.332
	"Three mutual" standardization rate	0.334
Reduce the inventory number of spare parts	Implementation rate of green standards	0.332
	Interchangeability rate	0.332
	"Three mutual" standardization rate	0.336
Increase the production batch of green products	Implementation rate of green standards	0.33
	Interchangeability rate	0.333
	"Three mutual" standardization rate	0.337

4.3.3. Entropy of the Standardized Value of a Single Index

If relevant personnel measure the normalized value of the system through normalized entropy, they need to assign normalized value coefficients to events. The entropy for measuring the standardized value of the system can be expressed as:

$$S_v = -\ln(k_1 p_1 \cdot k_2 p_2 \cdots k_n p_n) = \sum_{i=1}^{n} -\ln k_i p_i \qquad (2)$$

In Formula (2), S_v is the entropy for measuring the normalized value of a system. Since the value brought by the standardization of different events k_i is different, each event has its own standardized value coefficient. The product of the value coefficient and event occurrence probability is the entropy S_v of standardized value measurement of the system.

It is not convenient to compare the entropy of different systems in the above formula, so it is necessary to normalize the events and their standardized value coefficients, and establish the comparability formulas of the standardized entropy of the following different systems:

$$S_{vu} = -\ln(c_1 p_1 \cdot c_2 p_2 \cdots c_n p_n) = \sum_{i=1}^{n} -\ln c_i p_i \qquad (3)$$

Where, S_{vu} is the unification entropy for measuring standardization value. $c_i = \frac{k_i}{k_1 + k_2 + \cdots + k_n}$ is the normalization coefficient of event value coefficient k_i. S_{vu} can be the evaluation entropy for standardized value unification.

Therefore, this article uses unification and standardization entropies to evaluate the standardized effectiveness entropy for green development of aviation equipment.

4.3.4. Comprehensive Evaluation of Standardization Effectiveness for Large and Complex Equipment

On the basis of index evaluation, the standardization effectiveness for green development of aviation equipment is comprehensively evaluated by comprehensive evaluation method. The model consists of three basic set conditions $(U\ V\ A)$. Among them, U is the factor set of the evaluation object, that is, various characteristics of the evaluation object. U is denoted as $U = (u_1, u_2, \ldots u_n)$.

V is a comment set, that is, the evaluation grade given to the evaluation object. V is denoted as $V = (S_{vu1}, S_{vu2} \cdots S_{vun})$.

Since each factor in U has different influence on the evaluation result, it is necessary to give different weights to each factor, and so the weight set A of each index is obtained. A is denoted as $A = (a_1, a_2 \cdots a_i \cdots a_m)$.

Where, a_i is the weight corresponding to the i_{th} factor, and it is specified that $\sum_{i=1}^{n} a_i = 1, (i = 1, 2. \cdots, n)$.

Comprehensive evaluationsynthesizes single-factor evaluation according to the weight of each factor, and B represents the set of comprehensive evaluation, and B is defined as shown below.

$$B = A \times S = (b_1, b_2, \cdots, b_i, \cdots, b_m) \qquad (4)$$

In the formula, $b_i = \sum_{k=1}^{n} a_k \square s_{vni}, (i = 1, 2, 3, \cdots m)$.

When there are many evaluation factors, the factors can be decomposed into several subsets according to the attributes such as parallelism and causality. For each subset, a first-level comprehensive evaluation is conducted according to the above evaluation method. The results of the first-level comprehensive evaluation are listed in a single-factor evaluation matrix, and the weight distribution is given according to the importance principle. Then, matrix operation is carried out to obtain the second-level comprehensive evaluation. In the comprehensive evaluation, according to the specific situation of evaluation, multiple cycles can be carried out to realize a multi-level comprehensive evaluation.

4.4. Case Analysis

4.4.1. Analysis of the Standardization Situation in the Development of the a-Type Helicopter

A-type helicopter is a multi-purpose helicopter. In order to strengthen the work of A-type helicopter chief designer system and improve the standardized technical management, the type general command system and chief designer system decided to set up a standardized work system for the change of helicopter. Moreover, documents such as "Standard and Standard Parts Selection Range" and "Mainframe Material Selection Range" were prepared and implemented dynamic management.

An equipment standard system consisting of more than 5,700 standards has been constructed in the development of a certain helicopter, which provides a standard basis for equipment development. These standards include 303 international green standards, 1,183 national standards, 935 national military standards, 1,515 industry standards, more than 1,294 enterprise standards, and about 500 type-specific standards.

4.4.2. Standardization Rate of Each Event in A-Helicopter

The standardization rate of each event of the A-type helicopter was counted based on the investment in human, material, and institutional resources, the construction of the standard system, the implementation of the standard and the evaluation of the analysis. The standardization rate of each standardization event is shown in Table 6.

Table 6. Standardization rate of each standardized event in A- type helicopter development.

Serial number	Standardized events	Standardization rate
1	Standardization rate of technical status documents	99%
2	Standardization rate of core business processes	22.70%
3	Standardization rate of job operation	90%
4	Standardization rate of major standards	90%
5	General standard adoption rate	73.90%
6	Green international standard adoption rate	1.40%
7	Green internal standard adoption rate	21.30%
8	Standardization rate of green technology	95%
9	"Three orientations" rate of products	93.30%
10	"Three orientations" rate of tooling	46.80%
11	"Three mutual" standardization rate	70%
12	Process standardized rate	90%
13	Green parts standardization coefficient	86.40%
14	Green material standardization coefficient	50.80%
15	Standardization rate of software interfaces	75%
16	Standardization rate of software components	75%
17	Inheritance rate	6.50%
18	Interchangeability rate	81.10%
19	Standard conversion promotion rate	8.70%

4.4.3. Single indicator standardized entropy determination

Based on the standardization rate of events, combined with the value coefficients of events of aviation equipment, the article uses equation (3) to calculate the value coefficients of each indicator of the standardized effectiveness of this type of helicopter as shown in Table 7

Table 7 Value coefficients of standardized effectiveness indicators for each finger of A-type helicopter

Serial number	Indexes	Value coefficient
1	Promote the application of advanced green technology	0.328
2	Facilitate the transformation and promotion of green technology	0.589
3	Promote and enhance the maturity of new technologies	0.463
4	Standardize the process development system	0.627
5	Promote compliance and reduce risks	0.765
6	Improve the quality control level	0.593
7	Standardize technical status management	0.789
8	Promote project integration and collaboration	0.836
9	Improve green product design reuse	0.655
10	Reduce green product design defects	0.717
11	Reduce green product design changes	0.716
12	Reduce the risk of technology development	0.715
13	Improve green process rate	0.718
14	Reduce the preparation time before production	0.623
15	Improve the application of green materials	0.640
16	Reduce green product manufacturing costs	0.633
17	Reduce the cost of green product inspection	0.625
18	Increase the production batch of green products	0.647
19	Reduce the number of trainings	0.804

Serial number	Indexes	Value coefficient
1	Promote the application of advanced green technology	0.328
2	Facilitate the transformation and promotion of green technology	0.589
3	Promote and enhance the maturity of new technologies	0.463
20	Reduce green repair and maintenance costs	0.803
21	Reduce the inventory number of spare parts	0.803
22	Improve the level of green usage	0.803

Based on the standardized effectiveness value coefficient of each indicator of the A-type helicopter, the standardized entropy of each indicator was calculated by applying equation (3), and the results are shown in Table 8.

Table 8. Standardized entropy for each finger of the A-type helicopter.

Serial number	Indexes	Entropy
1	Promote the application of advanced green technology	0.219
2	Facilitate the transformation and promotion of green technology	1.546
3	Promote and enhance the maturity of new technologies	0.529
4	Standardize the process development system	0.467
5	Promote compliance and reduce risks	0.268
6	Improve the quality control level	0.523
7	Standardize technical status management	0.237
8	Promote project integration and collaboration	0.179
9	Improve green product design reuse	0.423
10	Reduce green product design defects	0.333
11	Reduce green product design changes	0.334
12	Reduce the risk of technology development	0.335
13	Improve green process rate	0.331
14	Reduce the preparation time before production	0.473
15	Improve the application of green materials	0.467
16	Reduce green product manufacturing costs	0.446
17	Reduce the cost of green product inspection	0.457
18	Increase the production batch of green products	0.470
19	Reduce the number of trainings	0.435
20	Reduce green repair and maintenance costs	0.218
21	Reduce the inventory number of spare parts	0.219
22	Improve the level of green usage	0.219

The standardized value coefficient is the weighted value of the indicator. Therefore, it is between 0 and 1. In addition, the standardized entropy is the -LN of the normalized standardized value coefficient, which leads to a range of (0-∞). However, since the standardization of each event cannot be 0, the standardized entropy of each indicator takes a value range between (0-5). Therefore, the closer the standardized entropy is to 0, the more orderly the event is, which means the higher the standardized effectiveness. The higher the standardized entropy, the more disorderly the event is, which means the lower the standardization effectiveness.

As can be seen from Table 8, except for facilitating the transformation and promotion of green technology, the standardization entropy of every single indicator of the A-type helicopter is much less than 1.000. Therefore, the standardization effectiveness of the helicopter is better.

4.4.4. Determination of Standard Entropy of a-Type Helicopter

On the basis of index entropy calculation, combined with the weight of each index, the overall entropy of standardized effectiveness for the modified helicopter is determined. According to Equation (4), the entropy of the five first-level indicators can be calculated.

Taking the engineering management optimization as an example, its index entropy is calculated to be 0.296.

$$b_1 = a_1 * S_{VU1} = [0.045 \quad 0.275 \quad 0.149 \quad 0.498 \quad 0.033] * \begin{bmatrix} 0.467 \\ 0.268 \\ 0.523 \\ 0.237 \\ 0.179 \end{bmatrix} = 0.296$$

Similarly, the article calculates the results of the entropy of the four indicators of improving green equipment development efficiency, creating green production scale effect, boosting the green usage and support effectiveness, and driving the application of green technology as 0.339, 0.453, 0.219, and 1.046, respectively. On this basis, the overall entropy of helicopter standardization effectiveness calculated is 0.425, which indicates that the helicopter performs extremely well in terms of standardization effectiveness. The details of the sub-indicators are shown in Figure 11.

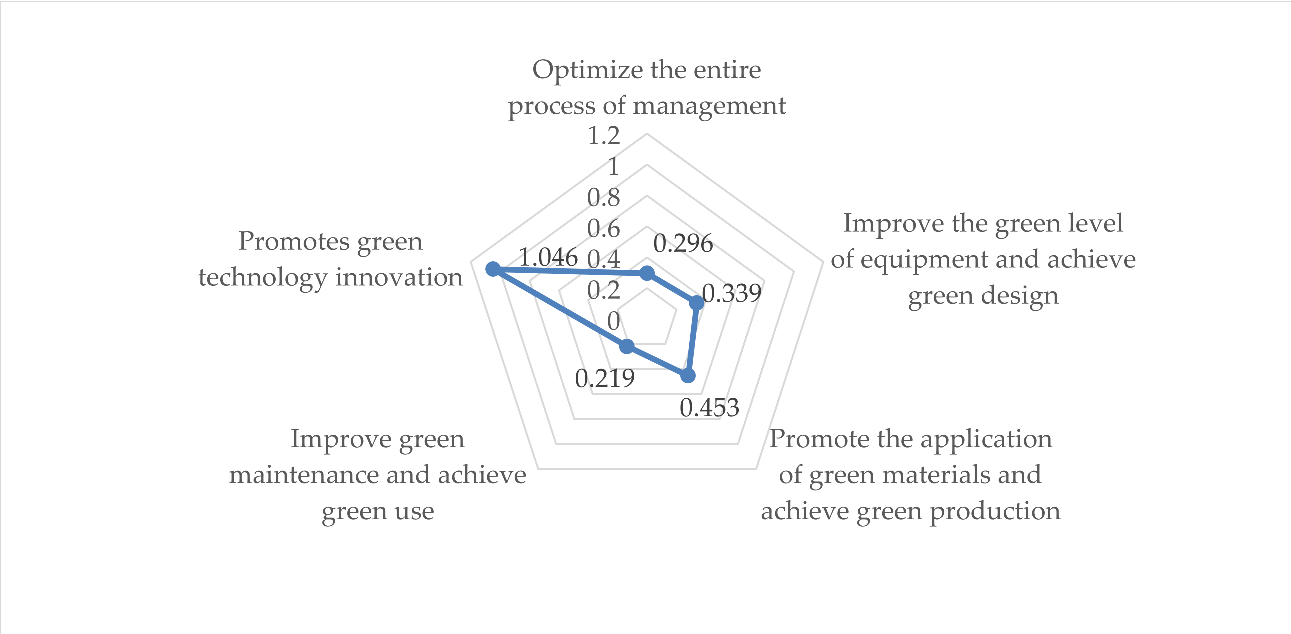

Figure 11. Standardized entropy spider web diagram of A-type helicopter sub-indicators

In Figure 11, the sub-indexes are Improve green maintenance and achieve green use (0.219), optimize the entire process of management (0.296), improve the green level of equipment and achieve green design (0.339), promote the application of green materials and achieve green production (0.453), promotes green technology innovation (1.046) respectively, in order of effectiveness from low to high. Therefore, the lowest efficacy is promotes green technology innovation. Overall, the standardization effectiveness of the helicopter as a good performance in the aspects of green use, the entire process management and green production, which can best reflect the standardization effectiveness. In summary, the standardization effectiveness of the A-type helicopter is good.

Conclusions

Guided by the system engineering theory and based on the construction of the system structure model for green development of aviation equipment, this study analyzes the mechanism of the standardization role in the development of aviation equipment, constructs the SEM-ANP-NE standardization effectiveness evaluation model, and conducts a case verification with a type of helicopter development as an example.

Based on the questionnaire analysis results, the score of each indicator is greater than 0.35(the highest score is 5). Due to the survey covering aviation equipment design organizations, manufacturing organizations, user organizations, higher education institutions, etc., the statistical results are reliable. Therefore, the evaluation index system of standardization promotes green development of aviation equipment has high scientific and operability. The standardized value coefficients of each indicator are surveyed using the same method, and the scoring of each expert is consistent. So, the value coefficient of each indicator is scientific and reliable. The index data are obtained by statistics, which is obviously advanced and the evaluation result is more accurate than the original subjective expert scoring method.

In the design of weights, the article uses network hierarchical analysis method, which is based on the basic principle of hierarchical analysis method and considers the relationship between indicators, making the calculation of weights of indicators more reasonable.

Based on standardized events, the effectiveness evaluation analyzes the value coefficients of each standard event and calculates the standardized effectiveness entropy of a single indicator from the principle of standardized occurrence. In turn, the overall entropy of standardization effectiveness for green development of aviation equipment is determined by combining the weights, so that the effectiveness of standardization can be measured in the form of standardization entropy. This study provides theoretical and methodological support for the mechanism of standardization effectiveness generation and the measurement of standardization effectiveness.

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