Comprehensive Evaluation of Civil Aviation Senior Inspector Competence Based on Cloud Model

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Abstract: The role of senior aviation inspectors as exemplar leaders in industry regulatory enforcement plays a crucial role in enhancing the regulatory enforcement capabilities of all inspectors, consolidating the "three foundations" of civil aviation regulatory work, and advancing the modernization of the governance system and governance capabilities in the civil aviation industry. To evaluate the work of senior aviation inspectors better, a competency assessment indicators system for senior inspectors was constructed based on the foundation of "One Quality, Three Capabilities" combined with job requirements. Finally, a comprehensive evaluation cloud chart generated by the cloud model was used to assess the competency levels of senior aviation inspectors. Applying this method to evaluate the comprehensive capability of senior inspectors in a certain regulatory bureau, the results indicate that the integrated competency of the senior inspector is close to an excellent level, with outstanding professional competence reaching an excellent level, while other competencies are at an above-average level. The evaluation results align with the actual work performance of the senior inspector, validating the rationality of the evaluation indicators system and the applicability of the evaluation method. The evaluation results can serve as a reference for the performance appraisal of senior inspectors and the improvement of inspector capabilities.

Keywords: Civil Senior Aviation Inspectors; Competency Evaluation; Entropy Weights; Cloud Model

1. Introduction

In response to the rapid development of China's civil aviation industry, the modernization of the regulatory system has become increasingly prominent in its significance and urgency. Within the civil aviation regulatory workforce, senior civil aviation inspectors, recognized as experienced, disciplined, and highly skilled experts in the field of civil aviation regulation, not only represent the highest professional standards and law enforcement credibility in the civil aviation industry, but their outstanding problem-solving abilities, innovation, and leadership will determine the future direction of the industry.

In 2020, the Civil Aviation Administration of China issued the "Notice on Printing and Distributing the Implementation Measures for the Recognition of the First Batch of Senior Inspectors by the Civil Aviation Administration of China" and the list of the first batch of senior inspectors. In 2021, it further issued the "Implementation Plan for the First Selection and Evaluation of Senior Inspectors in Chinese Civil Aviation" aiming to promote the construction of the senior inspector workforce and enhance their regulatory and law enforcement capability.

It is worth noting that, despite the well-defined selection methods for senior inspectors, comprehensive research on the job performance evaluation of existing senior inspectors has not been fully initiated. Establishing a comprehensive research and evaluation mechanism is not only a pressing current need but also a crucial element in ensuring the integrated development and continuous improvement of regulatory standards within the civil aviation inspection workforce. Such a mechanism can provide clearer development directions for individual inspectors and contribute to the formation of a more scientific and efficient regulatory system within the industry. This, in turn, lays a solid foundation for the sustainable development of China's civil aviation industry.

In the existing research on the competence assessment of civil aviation inspectors, Chen Fang et al. proposed a competence model for civil aviation air traffic management system inspectors from four aspects: education, training, skills, and experience. This model aims to address the inconsistent business capability and varied inspection standards within the inspector workforce. The authors emphasized that skills and experience are critical factors in assessing the competence of inspectors, offering the potential to enhance inspection consistency and efficiency, ensuring the safety quality of the air traffic management system [1].

Li Xiang et al. conducted a systematic analysis of the FAA safety inspection system, providing valuable suggestions for the construction of China's civil aviation safety inspection system. They highlighted the relatively weak soft skills and database usage skills of inspectors and recommended strengthening communication, coordination, emergency handling, inspection support system, and database application capability in China to enhance integrated inspection efficiency [2].

Luo Feng'e et al., from the perspective of on-the-job training, established an evaluation indicators system for the training competence of aviation safety inspectors. Using fuzzy analytic hierarchy process, they calculated the weights of the indicators, providing a theoretical basis for in-service training of aviation safety inspectors in China. This approach makes training more targeted, contributing to the systematic improvement of trainees' abilities [3].

Gao Bo et al. proposed an aviation inspector competence assessment method based on an improved entropy-cloud model. They constructed an inspector competence evaluation indicators system, assigned weights to the indicators using the improved entropy method, and introduced the cloud model to generate a comprehensive evaluation cloud map, specifying inspector competence levels [4].

Senior inspectors share similar traits with senior managers in enterprises. Hence, insights from related research on the evaluation of senior management capability can be applied. Hogan and Warrenfeltz suggested covering four skill categories when evaluating senior executives: self-management capability, interpersonal capability, leadership, and business capability. Among these, the cultivation of self-management capability is emphasized as more advantageous than business capability [5].

Pedler, Burgoyne, and Boydell proposed at least 10 quality indicators for evaluating senior executives, including basic knowledge of the organization, relevant professional knowledge, sensitivity and continuous attention to relevant events, analytical, judgment, and decision-making abilities, social capability, emotional resilience, the ability to respond to unforeseen events with a long-term perspective, creativity, mental agility, and learning capacity [6].

Zhang Xianglin advocated for establishing a scientifically socialized talent evaluation system, emphasizing the combination of theory and practice. He suggested improving evaluation standards, avoiding excessive focus on qualifications and seniority, and neglecting competence and actual performance. He proposed a comprehensive talent evaluation system including character, knowledge, and ability, with performance at its core [7].

The aforementioned studies provide theoretical support for the competence assessment system of senior inspectors and offer practical guidance for the selection, training, and professional development of civil aviation senior inspectors. This contributes to ensuring the efficient operation of aviation safety and regulation. It is essential to highlight that, in past research, there existed a theoretical gap in the assessment of the job capabilities of senior civil aviation inspectors, and this paper addresses this gap. In practical application, this positively aids the healthy development of the senior inspector workforce in civil aviation, providing valuable reference and expansion space for future research.

2. Competency Evaluation Indicators System and Level Classification for Senior Civil Aviation Inspectors

2.1 Competency Evaluation Indicators System for Senior Civil Aviation Inspectors

"One Quality, Three Capabilities" (political literacy, competence in legal thinking and legal approaches, industry management capabilities, and professional capabilities) are the fundamental standard for evaluating civil aviation inspectors. In comparison to general inspectors, senior inspectors are expected to exhibit a commitment to lawful administration, exceptional professional expertise, a proactive role in advancing regulatory improvements, and a driving force in the development of regulatory teams. To better align with the practical needs of senior civil aviation inspectors, we have developed an evaluation framework for the capabilities of senior inspectors, as illustrated in Figure 1, through discussions with selected senior inspectors.

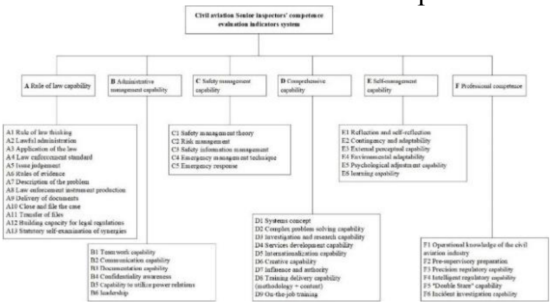

Figure 1. Civil Aviation Senior Inspectors' Competence Evaluation Indicators System

2.2 Civil Aviation Senior Inspector Capability Evaluation Levels

After establishing a robust capability evaluation indicators system, the next step involves inviting civil aviation inspectors to participate in a symposium. During this session, elucidate the meaning of each indicator and distribute questionnaires to allow them to rate the importance of each standard. Subsequently, utilize the entropy weight method to calculate the weights of each evaluation standard. Finally, employ cloud model techniques to determine the capability levels of civil aviation senior inspectors. The detailed evaluation process is illustrated in Figure 2.

This approach draws inspiration from the "Guidelines for the Implementation of Outstanding Performance Evaluation Standard" (GB/Z 19579-2012), the "Regulations on Personnel Management of Institutions" (State Council Order No. 652), and the "Regulations on Civil Servant Assessment" (2020). Most literature adopts a scoring range of "0-100 points" Considering that senior civil aviation inspectors are elite members of the regulatory team, there is no concern about exceptionally low scores for any specific standard. Therefore, the capability levels for senior civil aviation inspectors are classified from Level I to Level III, with the score range restricted to "60-100 points" The corresponding score intervals are outlined in Table 1.

Table 1. Civil Aviation Senior Inspectors Competency Level Classification Standards

Competency level	Score range
I（Medium）	$(60, 75]$
II（Good）	$(75, 90]$
III（Excellent）	$(90, 100]$

3. Evaluation Method Based on Entropy Weight-Cloud Model

According to the constructed competence evaluation index system, a questionnaire was used to invite senior civil aviation inspectors to rate the importance of the indexes, the entropy weighting method was used to determine the weights of the evaluation indexes, and the competence level of the senior inspectors was determined with the help of the cloud model, and the specific evaluation process is shown in Figure 2.

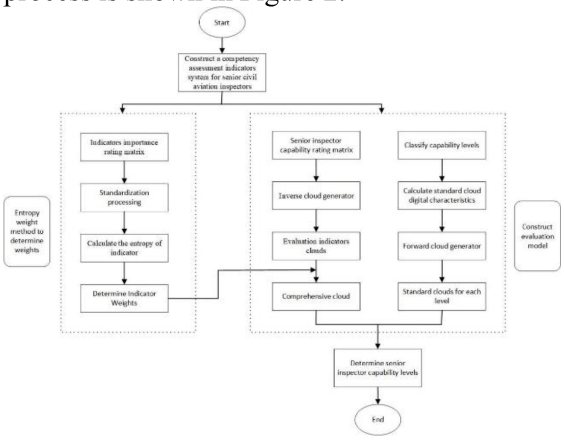

Figure 2. Flow Chart of Entropy-cloud Model Evaluation Method

3.1 Determine Indicators Weights

The evaluation of the capabilities of senior civil aviation inspectors is a comprehensive, multi-level and multi-faceted systematic assessment. It requires innovation while staying grounded in practical considerations. The evaluation indicators system includes qualitative indicators such as rule of law capability, administrative management capability, safety management capability, comprehensive capability, self-management capability, and professional competence. The work of senior civil aviation inspectors leans towards strategic orientation, decision innovation, and team building, and as such, lacks quantitative assessment indicators such as workload and work efficiency.

Information entropy is a concept used to measure the uncertainty and chaos within an information system, describing the magnitude of the average information contained in events. The entropy weight method, based on the principles of information entropy, is employed to determine the importance of indicators [8-10]. The calculation steps are as follows:

Construction of the importance rating matrix for the capability evaluation indicators of senior civil aviation inspectors X_{ij}.Evaluation target set as $\{R_i\}(i = 1,2,3, \ldots, n)$, The set of evaluation indicators is $\{R_j\}(j = 1,2,3, \ldots, m)$, among others x_{ij} is the raw importance rating of expert i for indicator j

$$X_{ij} = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \quad (1)$$

Perform the standardization of the importance scoring matrix. X_{ij} is processed according to equation (2) to obtain the standardized matrix Z_{ij}, and at the same time, the contribution of the i expert's rating in the j indicator's importance rating, p_{ij} is calculated according to equation (3).

$$z_{ij} = \frac{x_{ij} - min(x_j)}{max(x_j) - min(x_j)} \quad (2)$$

Where z_{ij} denotes the normalized value, and $max(x_j)$ and $min(x_j)$ denote the maximum and minimum values of the expert's importance rating of indicator j, respectively.

$$\mathrm{p_{ij}} = \frac{\mathrm{z_{ij}}}{\sum_{\mathrm{j=1}}^{\mathrm{m}} \mathrm{z_{ij}}} \quad (3)$$

Calculate the entropy value (e_j) for indicator j.

$$e_j = -\frac{1}{ln(n)} \sum_{j=1}^{m} p_{ij} \, ln(p_{ij}) \quad (4)$$

In the formula, when $p_{ij} = 0$, let $lnp_{ij} = 0$.

Calculation of the weights (w_j) of the indicator j.

$$w_j = \frac{1 - e_j}{m - \sum_{j=1}^{m} e_j} \quad (5)$$

3.2 Cloud-based Model for the Capability Assessment of Civil Aviation Inspectors

The cloud model is a mathematical model that integrates fuzzy mathematics, probability statistics, and artificial intelligence theories. Through digital characteristics such as expectation, entropy, and hyper-entropy, it effectively deals with uncertainty, fuzziness, and randomness. It finds extensive applications in areas such as information fusion and decision support [11-13]. When evaluating the capabilities of senior civil aviation inspectors, the application of the cloud model effectively addresses the issues of fuzziness and randomness introduced by different expert ratings, enhancing the scientific and reliable nature of the evaluation results. The specific steps are as follows:

Constructing the civil aviation senior inspector competency evaluation standard cloud. According to the civil aviation senior ombudsman competence level classification standard, use equation (6) to calculate the digital characteristics of each level of standard cloud (E_{xi}, E_{ni}, H_{ei}).

$$\begin{cases} E_{xi} = \frac{x_i^{max} + x_i^{min}}{2} \\ E_{ni} = \frac{x_i^{max} - x_i^{min}}{6} \\ H_{ei} = k \end{cases} \quad (6)$$

In the above equation, $[x_j^{min}, x_j^{max}]$ corresponds to the range of competency level scores specified herein; k is a constant , selecting based on the fuzzy threshold of the variable, usually take 0.01、0.5、1, this paper takes $k = 0.5$ [14].

Constructing the civil aviation senior inspector competency evaluation indicators cloud. Assuming that experts are involved in scoring the competence of the civil aviation senior inspector, the competence indicator scores are calculated using the equation (7), and the digital characteristics of the indicator cloud for each indicator are determined(E_{xj}, E_{nj}, H_{ej}).

$$\begin{cases} E_{xj} = \frac{1}{n} \sum_{i=1}^{n} Z_{ij} \\ E_{nj} = \sqrt{\frac{\pi}{2} \frac{1}{n}} \sum_{i=1}^{n} |Z_{ij} - E_{xj}| \\ H_{ej} = \sqrt{|S_j^2 - E_{nj}^2|} \\ S_j^2 = \frac{1}{n-1} \sum_{i=1}^{n} (Z_{ij} - E_{xj})^2 \end{cases} \quad (7)$$

In the equation, E_{xj} represents the cloud expectation of indicator j; E_{nj} represents the cloud entropy of indicator j; H_{ej} represents the cloud hyperentropy of indicator j; Z_{ij} indicates the scoring matrix of the experts; S_j^2 denotes the standard deviation of experts' ratings for indicator j.

Constructing a comprehensive cloud for the capability assessment of senior civil aviation inspectors. The results of n experts' scores for each metric are weighted and integrated according to Eq. (8), and finally the integrated cloud digital characteristics (E_x, E_n, H_e) are obtained.

$$\begin{cases} E_x = \sum_{j=1}^{n}\left(E_{xj} \cdot w_j\right) \\ E_n = \left[\sum_{j=1}^{n}\left(E_{nj}^2 \cdot w_j\right)\right]^{\frac{1}{2}} \\ H_e = \sum_{j=1}^{n}\left(H_{ej} \cdot w_j\right) \end{cases} \quad (8)$$

4. Example Applications

4.1 Calculation of the Weights of the Indicators for Evaluating the Competence of Senior Civil Aviation Inspectors

In order to scientifically and objectively determine the weights of each evaluation standard, we invited a total of 342 participants, including inspectors and industry experts from various regional regulatory authorities. The breakdown is as follows: (1) Regulatory inspectors - 229, Supervisory inspectors - 43, Civil aviation industry experts - 70; (2) Aviation safety - 33, Flight standards - 26, Airworthiness approval - 9, Airports - 23, Aviation security - 25, Air traffic management - 29, Emergency management - 20, Network and information security - 22, Public air transport - 21, General aviation market - 23, Price statistics - 22, Finance - 15, Comprehensive - 12, Others - 62; (3) Work experience in civil aviation supervision or related fields: 2 years and below - 20, 2-5 years - 32, 5-10 years - 133, over 10 years - 157

We employed the "Likert five-point scoring method" through an online questionnaire to assess the importance of evaluation indicators for senior civil aviation inspectors [15]. The obtained importance ratings for each indicator were then calculated using formulas (2)-(5), resulting in the indicators weights as presented in Table 2.

4.2 Identification of Evaluation Standard Cloud

According to the classification of capability levels and score intervals for senior civil aviation inspectors outlined in Table 1, the calculation of the standard cloud digital characteristics for each capability level was conducted using Equation (6), as depicted in Table 3.

According to the forward cloud algorithm, the standard cloud digital characteristics for each capability level from Table 3, along with 2000 cloud droplet quantities, were used as inputs to sequentially generate standard cloud diagrams for the three capability levels, as illustrated in Figure 3. Levels I to III are represented in blue, red, and yellow, respectively.

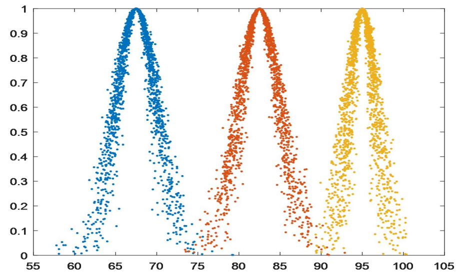

Figure 3. Evaluation of the Standard Cloud Chart

4.3 Calculation of Individual Metrics Clouds and Composite Clouds

Taking a senior civil aviation inspector of a regional administration who has been engaged in inspection work for 15 years as the object of evaluation, six experts from the unit where the senior inspector is located are invited to give objective scores on his ability, and the scores are based on the percentage system. Through the inverse cloud algorithm, the scoring results are calculated according to equation (7) to obtain the cloud digital characteristics of each indicator $\left(E_{xj}, E_{nj}, H_{ej}\right)$, and the results are shown in the fifth column of Table 2. The cloud digital characteristics and weights of each indicator are brought into equation (8), and the digital characteristics of the first-level indicators are calculated: rule of law capacity (85.57, 7.72, 2.34), administrative management capacity (85.84, 6.29, 2.12), safety management capacity (86.05, 7.66, 2.15), comprehensive capacity (85.73, 6.46, 2.05), self-management capacity (83.56, 6.11,1.94), and professional competence (90.05, 5.33, 1.81). Similarly, through the forward cloud generator, the digital characteristics of the first-level indicators and the number of 2000 cloud drops were used as inputs to draw the cloud map of the first-level indicators as shown in Figures 4 to 7.

Substituting the digital characteristics of each level of indicators into equation (8), the integrated cloud digital characteristics of civil aviation senior ombudsman competence evaluation are calculated as (86.11,6.71,2.08), and the integrated competence cloud diagram is plotted as shown in Figure 8.

Table 2. Weights of Each Evaluation Indicator

First-level indicators	Weights	Second-level indicators	Weights	digital characteristics
Rule of Law Capacity A	18.59%	A1	7.67%	(87.33, 3.9, 1.52)
		A2	7.54%	(85, 6.68, 2.26)
		A3	7.47%	(78, 5.01, 1.86)
		A4	8.45%	(81.33, 11.14, 3.09)
		A5	8.43%	(77.67, 8.91, 2.7)
		A6	8.01%	(88.33, 3.62, 1.43)
		A7	8.27%	(87, 9.19, 2.76)
		A8	6.11%	(80.33, 8.91, 2.71)
		A9	7.20%	(84.33, 10.31, 2.96)
		A10	8.22%	(91.33, 6.96, 2.32)
		A11	7.41%	(87, 6.68, 2.26)
		A12	7.64%	(89.33, 9.47, 2.81)
		A13	8.21%	(87.33, 3.9, 1.53)
Administrative Management Capability B	15.71%	B1	16.90%	(83.33, 8.08, 2.55)
		B2	15.99%	(89.67, 7.24, 2.38)
		B3	16.37%	(85.33, 5.57, 2.00)
		B4	17.69%	(82.33, 5.29, 1.93)
		B5	19.47%	(82, 3.34, 1.33)
		B6	16.43%	(78.67, 6.96, 2.32)
Safety Management Capability C	17.79%	C1	21.17%	(84.67, 7.8, 2.50)
		C2	19.15%	(90, 6.68, 2.26)
		C3	22.44%	(81, 9.19, 2.76)
		C4	17.67%	(88, 10.03, 2.91)
		C5	19.07%	(90, 1.67, 0.32)
Comprehensive Capability D	17.75%	D1	12.83%	(89.33, 3.9, 1.53)
		D2	11.31%	(80.33, 3.62, 1.43)
		D3	10.44%	(82, 3.34, 1.33)
		D4	11.20%	(86, 8.36, 2.60)
		D5	11.30%	(85.67, 7.24, 2.38)
		D6	11.11%	(84, 10.03, 2.91)
		D7	9.67%	(82, 3.34, 1.33)
		D8	11.77%	(84.67, 7.8, 2.50)
		D9	11.72%	(86, 5.85, 2.07)
Self-Management Capability E	14.80%	E1	15.45%	(79, 8.36, 2.60)
		E2	17.25%	(90, 4.18, 1.61)
		E3	17.54%	(88.67, 4.46, 1.70)
		E4	18.11%	(85, 9.19, 2.76)
		E5	14.42%	(84, 4.18, 1.61)
		E6	14.78%	(86.33, 3.9, 1.53)
Professional Competence F	15.36%	F1	17.23%	(92.33, 3.62, 1.43)
		F2	16.15%	(85, 8.36, 2.60)
		F3	15.68%	(88.33, 4.73, 1.78)
		F4	20.68%	(86, 5.85, 2.07)
		F5	15.85%	(88, 2.51, 0.97)
		F6	16.59%	(89.33, 4.46, 1.70)

Table 3. Evaluation Level and Standard Cloud Digital Characteristics Comparison Table

Competency level	Score range	Standard cloud digital characteristics
I（Medium）	(60, 75]	(67.5, 2.5, 0.5)
II（Good）	(75, 90]	(82.5, 2.5, 0.5)
III（Excellent）	(90, 10(	(95.0, 1.7, 0.5)

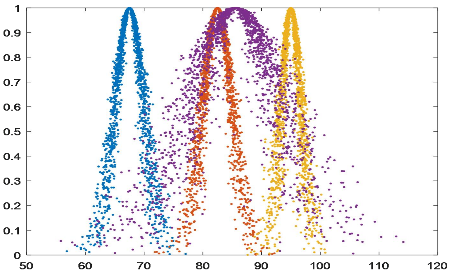

Figure 4. Rule of Law Capacity Indicator Cloud Chart

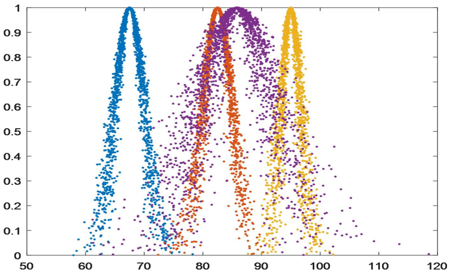

Figure 5. Administrative Management Capability Indicator Cloud Chart

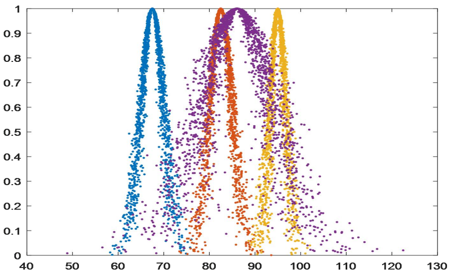

Figure 6. Safety Management Capability Indicator Cloud Chart

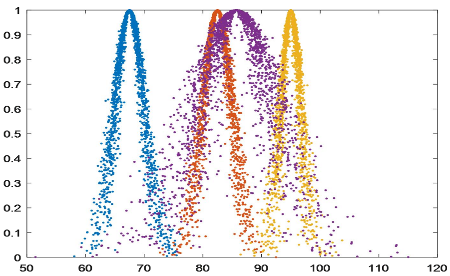

Figure 7. Comprehensive Capability Indicator Cloud Chart

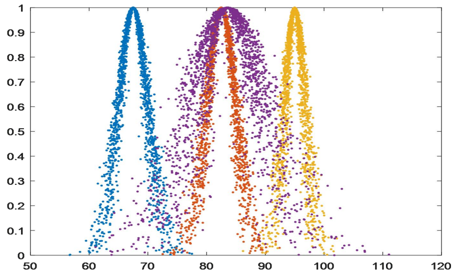

Figure 8. Self-management Capability Indicator Cloud Chart

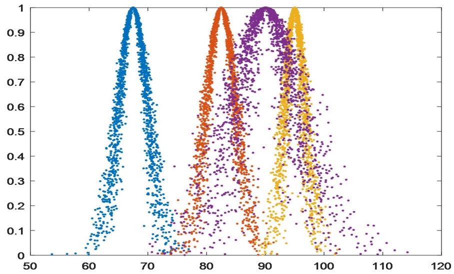

Figure 9. Professional Competence Indicator Cloud Chart

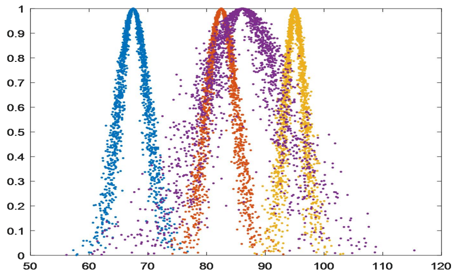

Figure 10. Civil Aviation Senior Inspector Integrated Capability Cloud Chart Indicator Cloud Chart

4.4 Analysis of Evaluation Results

Combining the digital characteristics of each evaluation standard from Table 2, the analysis is as follows:

(1) From Figures 4 to 10, it is evident that the cloud layer thickness, cloud droplet dispersion, and span range of each first-level indicator evaluation cloud are much larger than the standard clouds for each level. This indicates that there are slight differences in the evaluation standard for various capabilities among different experts, aligning with normal logical thinking and reflecting the stochastic and fuzzy characteristics inherent in the process of evaluating the capabilities of senior civil aviation inspectors.

(2) Observing Figures 4 to 9, it can be deduced that the senior inspector's evaluations for the standard of legal competency, administrative

management capability, safety management capability, comprehensive capability, and self-management capability fall between "Level II" and "Level III" This suggests that the inspector's performance in these five indicators ranges from good to excellent, leaning towards excellent. The evaluation result for the professional competence standard is at "Level III" indicating an excellent performance in professional abilities.

(3) As seen in Figure 10, the integrated evaluation result for the senior inspector's capabilities falls between "Level II" and "Level III" indicating a performance ranging from good to excellent but close to an excellent level. In the workplace, the senior inspector exhibits strong professional capability and demonstrates robust legal competency, administrative management capability, safety management capability, comprehensive capabilities, and self-management capability. This assessment aligns with the integrated evaluation of the inspector's performance by colleagues in the same unit, indicating that the application of the entropy weight-cloud model evaluation method for comprehensively assessing the capabilities of senior civil aviation inspectors is creative, scientific, and accurate.

5. Conclusions

Through our research, we have constructed an evaluation indicators system for the capabilities of senior civil aviation inspectors. We utilized the entropy weight method to determine the weights of the indicators and employed the cloud model evaluation method for assessment. This effort aims to provide a scientific basis for the construction of the civil aviation inspection team and the modernization of the industry governance system.

Based on the principles of "One Quality, Three Capabilities" relevant assessment documents for senior inspectors, and practical work requirements, we constructed an evaluation indicators system for the capabilities of senior civil aviation inspectors. The system includes six first-level indicators (legal competency, administrative management capabilities, safety management capabilities, comprehensive capability, self-management capabilities, and professional competence), with corresponding 45 second-level indicators. This system comprehensively represents the competency requirements of senior civil aviation inspectors.

By distributing questionnaires to industry experts and inspectors, we collected data, calculated indicators weights using the entropy weight method, and used the cloud model to evaluate the capability levels of senior inspectors. This resulted in a complete set of indicator weights and cloud model digital characteristics.

Using the work performance of a specific senior civil aviation inspector as a reference, we invited six experts from their unit to score their performance according to the evaluation system. By comparing the evaluation results with the actual work performance, we validated the scientific and accurate nature of the entropy weight-cloud model evaluation method.

The constructed evaluation system in this study may require refinement in certain areas. Some indicators lack detailed definitions, some are challenging to quantify, and others have ambiguous scopes. Future improvements should be made in collaboration with industry experts' opinions and suggestions during practical usage. To address areas in which senior civil aviation inspectors show room for improvement, targeted training programs should be developed, contributing to the betterment of the civil aviation inspection team and the advancement of the modernization of the civil aviation industry governance system and capabilities.

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