High-Speed Rail Freight Risk Assessment Based On AHP-Cloud Model

Zherui Chen, Shuai Zheng

Abstract— **With the rapid development of the logistics industry, people have higher and higher requirements for the timeliness of logistics. As a new mode of transportation, high-speed rail freight express can effectively reduce the environmental pollution caused by road transportation, and is of great significance in promoting the sustainable development of high value-added and small-batch cargo transportation. Railway enterprises use high-speed rail train confirmation cars, idle carriages, large luggage storage and other locations to carry out high-speed rail express transportation, giving full play to the advantages of high-speed rail transportation, but while improving economic and social benefits, it also poses challenges to the safety of high-speed rail operation. In this paper, the high-speed rail freight safety evaluation is taken as the research object, and the combination of analytic hierarchy process (AHP) and cloud model model is used to construct a high-speed rail freight safety evaluation model based on AHP-cloud model. Through the analysis of the influencing factors of high-speed rail freight safety, the key factors affecting safety were determined, and the AHP method was used to analyze the weight of each factor, and then combined with the cloud model model to quantify the safety evaluation criteria to obtain the safety evaluation grade. Finally, the feasibility and effectiveness of the model are verified by examples.**

Index Terms— **high-speed rail freight; AHP; safety evaluation; cloud model**

I. INTRODUCTION

With the rise of e-commerce platforms, domestic demand for express logistics services has surged. In recent years, China's express business volume has generally shown a growth trend. E-commerce consumption has become an indispensable part of people's lives, further driving the growth of logistics demand. The high-speed rail express service launched by China Railway Corporation has achieved deep integration of the logistics industry and high-speed rail freight, marking the logistics industry's entry into the high-speed rail era [1]. The continuous increase in China's railway operating mileage provides a solid foundation for high-speed rail freight transportation. By now, the national railway operating mileage has reached 155,000 kilometers, including 42,000 kilometers of high-speed railway. It is estimated that by 2025, the total railway scale will reach 175,000 kilometers, and by 2030, the railway operating mileage will be expanded to 200,000 kilometers, including approximately 45,000 kilometers of high-speed railway. This will achieve nationwide internal and external connectivity, smooth regional multi-routes, high-speed rail connections between provincial capitals, rapid arrival to prefecture-level cities, and basic coverage of counties [2]. The extensive coverage of high-speed rail not only provides more convenience for people's travel but also promotes the prosperous development of China's high-speed rail freight market.

In recent years, the transportation structure of railway freight has undergone significant changes. In addition to the transportation of bulk cargo, the proportion of high-value-added cargo transportation is also rising, driving railway freight towards greater efficiency and convenience [3]. High-speed rail performs particularly well in these areas, thus its share of the market is increasingly growing. The number of high-speed rail express items sent increased from 128.93 million in 2014 to 469.36 million in 2021, a growth of 264% over seven years. As an emerging logistics service product, although high-speed rail express currently holds a relatively small market share, it is gradually winning customer favor due to its advantages such as speed, punctuality, temperature control, and environmental friendliness [4]. With the rapid development of high-speed rail express, safety issues have also emerged. Due to the mixed transport of passengers and goods and the high operating speeds, failure to effectively ensure safety could result in significant losses.

Current commonly used methods for safety risk assessment of high-speed rail freight include the safety checklist method, fault tree analysis, analytic hierarchy process (AHP), fuzzy analysis, and fuzzy analytic hierarchy process (FAHP), etc. [5-6]. Among them, the safety checklist method and fault tree analysis struggle to quantify the operational risk of dedicated railway lines for dangerous goods; while AHP, fuzzy comprehensive evaluation, FAHP, and dynamic fuzzy theory can quantify evaluation results, these methods rely on the expert scoring method to determine indicator weights, leading to strong subjectivity and arbitrariness [7-8]. Some scholars use intelligent algorithms like neural networks, which require large sample data for training and learning. However, existing research has limited sample sizes, resulting in poor generalization of the evaluation results [9]. The cloud model is an uncertainty transformation model between qualitative concepts and their quantitative representations, formed by constructing specific algorithms based on probability theory and fuzzy set theory [10-11]. Compared to other risk assessment methods, the cloud model can quantify fuzzy evaluation data into certainty degrees, avoiding the fuzzification of original data. It can effectively solve the problem of excessive subjectivity in traditional risk assessment methods and is gradually being applied to many fields such as multi-criteria decision-making, risk assessment, and quality evaluation [12].

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II. SAFETY EVALUATION INDEX SYSTEM FOR HIGH-SPEED RAIL FREIGHT

High-speed rail express freight is characterized by diverse types of goods, high timeliness requirements, varying packaging specifications, and complex nature. Consequently, its transportation involves significant safety hazards, considerable operational difficulties, and increased management safety risks, placing higher demands on both personnel and equipment facilities. Since high-speed rail express utilizes regularly scheduled high-speed trains for small parcel transportation, its safety is directly linked to railway transport order and the safety of passengers' lives and property. Through analysis of the high-speed rail express business process, the main factors influencing its safety primarily include operational standardization, equipment and facility reliability, personnel compliance, and the completeness of safety management.

2.1 Operational Standardization

Whether operations are standardized is a crucial means and strong guarantee for achieving corporate objectives. High-speed rail freight operations involve numerous links with safety risks. Factors significantly impacting high-speed rail freight safety mainly include five aspects: machine-based security inspection, real-name consignment, cargo sorting, stacking/palletizing, and package opening inspection. According to the "Three 100% System" in express logistics, the implementation of machine security checks, real-name consignment, and package opening inspections directly affects the transportation environment of railway logistics. As cargo sorting currently relies mainly on manual labor, the accuracy rate of cargo sorting is an important indicator for assessing safety conditions. Considering that inconsistent parcel sizes and uneven stacking can easily lead to instability, the standardization of stacking/palletizing determines whether potential safety hazards can be eliminated to achieve safe production. Therefore, these five factors are selected as evaluation indicators affecting the safety of high-speed rail express. A sound and reasonable operational standard can guide employee behavior, improve work quality, and enhance the company's competitiveness.

2.2 Equipment and Facility Reliability

As the material foundation of the transportation process and a key guarantee for transport safety, the assured quality of facilities and equipment directly affects the safe execution of railway freight transport work. Equipment reliability refers to the ability of equipment to perform specified functions under stated conditions and within a given time frame. Key equipment for high-speed rail express includes security scanners, unit load devices (ULDs), trolleys, loading/unloading tools, dedicated channels for small parcels entering/leaving stations, and temporary storage areas for small parcels. The presence of dedicated inbound/outbound channels and temporary storage areas that comply with relevant legal regulations for high-speed rail freight significantly impacts the safety of high-speed rail express operations.

2.3 Personnel Compliance

Currently, many processes in high-speed rail freight transportation require manual participation and intervention. How to unify and standardize everyone's work standards is an urgent problem to solve. High-speed rail freight production operations, being time-sensitive and requiring high efficiency, place greater demands on staff's professional competence, psychological quality, and labor discipline.

2.4 Completeness of Safety Management

Railway safety management adheres to the principle of "safety first, prevention As the main focus, comprehensive management." China State Railway Group Co., Ltd. recently officially issued the "14th Five-Year Plan for Railway Safety Development," which systematically reviews the foundation and situation for railway safety development during the "14th Five-Year Plan" period, defines development goals, key tasks, and research directions. The issuance of this plan is significant for balancing development and safety and promoting the sustained and healthy development of railway safety. The plan indicates that railway enterprises need to strengthen the construction of a dual-prevention control system for safety (risk management and hidden danger investigation), build a "three-in-one" safety assurance system encompassing human prevention, physical prevention, and technical prevention, and enhance safety education and operational procedure assessments. It emphasizes always treating the safety of high-speed rail and passenger trains as the lifeline of the railway industry, regarding the continuous strengthening of the safety foundation as the fundamental strategy for safety work, preventing various safety risks, and constantly improving the level of railway safety management and the rule of law in safety production.

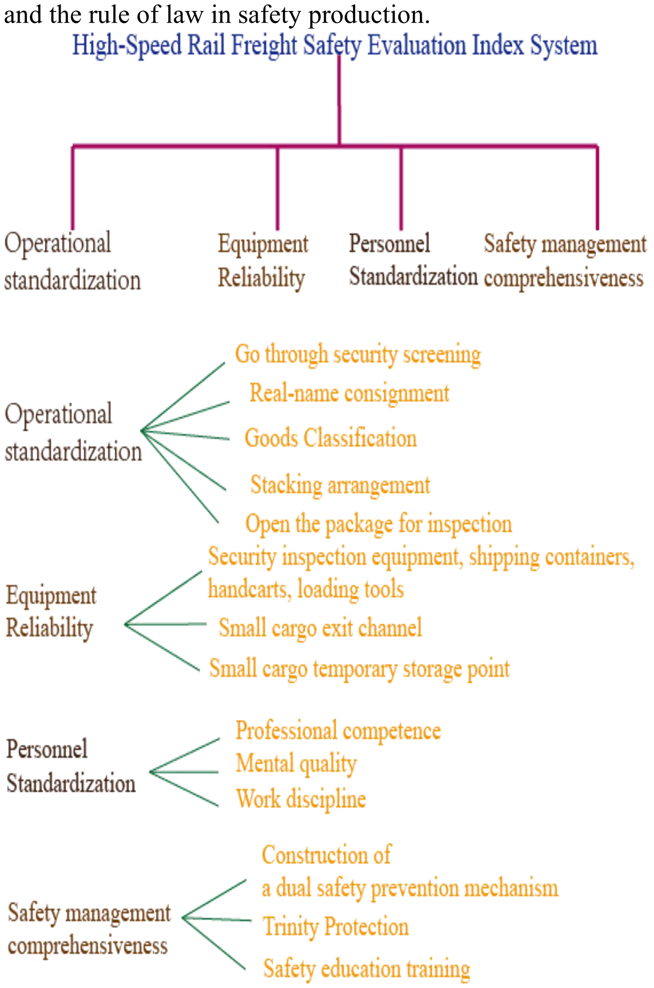

Figure 1 High-Speed Rail Freight Safety Evaluation Index System

III. AHP-Cloud Model Safety Evaluation Model for High-Speed Rail Freight

3.1 Introduction to the Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a research method that integrates qualitative and quantitative analysis, used to determine decision weights in complex multi-objective problems. AHP decomposes a decision-making problem into a hierarchical structure according to the sequence of the overall goal, sub-goals at various levels, evaluation criteria, and specific alternative plans. By solving for the eigenvectors of the judgment matrix, the priority weight of each element in a given layer relative to elements in the layer above is obtained. Finally, the weighted sum method is applied recursively to derive the final weight of each alternative with respect to the overall goal. The alternative with the highest final weight is considered the optimal solution.

Based on the nature of the problem and the overall objective to be achieved, AHP breaks down the problem into different constituent factors. These factors are then aggregated and combined according to their interrelationships and dependencies, forming a multi-level analytical structure model. Ultimately, the problem is reduced to determining the relative importance weight or ranking of the lowest-level elements (such as decision alternatives or measures) relative to the highest-level element (the overall goal).

The decision objective, the factors to be considered (decision criteria), and the decision alternatives are categorized into three levels—top, middle, and bottom—based on their mutual relationships, and a hierarchical diagram is constructed. The top level represents the purpose of the decision or the problem to be solved. The bottom level consists of the decision alternatives. The middle level includes the factors and decision criteria. For any two adjacent layers, the upper layer is referred to as the goal layer, and the lower layer as the factor layer.

In the second step, when determining the weights of factors at different levels, purely qualitative results are often difficult for others to accept. Therefore, Saaty et al. proposed the consistency matrix method, which involves comparing factors pairwise rather than all together. This approach uses a relative scale to reduce the difficulty of comparing factors with different attributes, thereby improving accuracy. Under a given criterion, the elements are compared in pairs and rated according to their importance. The outcome of comparing element *i* with element *j* is denoted, and Table 1 shows the nine levels of importance proposed by Saaty along with their assigned values. The matrix formed by the pairwise comparison results is called the judgment matrix.

Table 1 Matrix Element Importance Assessment

Factor i is greater than factor j	Quantitative value
Equally important	1
Slightly important	3
Relatively important	5
Strongly important	7
Extremely important	9
Intermediate value between two adjacent judgments	2、4、6、8

Step 3: Single-level Ranking and Consistency Check

The eigenvector corresponding to the largest eigenvalue λ_max of the judgment matrix is normalized (so that the sum of its elements equals 1) and denoted as **W**. The elements of **W** represent the ranking weights of the relative importance of factors at the same level concerning the factors at the next lower level. This process is referred to as single-level ranking.

To determine the allowable range of inconsistency for the judgment matrix, a consistency check is required. For a consistent matrix of order n, the only non-zero eigenvalue is n. For a positive reciprocal judgment matrix of order n, the largest eigenvalue λ_max ≥ n, and the matrix is consistent if and only if λ_max = n.

Step 4: Consistency Check

Considering that consistency deviation may arise from random causes, when testing whether the judgment matrix has satisfactory consistency, it is necessary to compare the Consistency Index (CI) with the Random Consistency Index (RI) to obtain the Consistency Ratio (CR). The formula is as follows:

$$CR = \frac{CI}{RI}$$

Generally, if the Consistency Ratio (CR) is less than 0.1, the judgment matrix is considered to pass the consistency test; otherwise, it does not exhibit satisfactory consistency.

3.2 Introduction to Cloud Model Evaluation

Let U be a quantitative domain and x be an element in U. If C is a qualitative concept in U, and the certainty degree μ(x)∈[0,1] of x with respect to C is a random number with a stable tendency, then the distribution of μ(x) over the quantitative domain U is called a normal cloud, with each x referred to as a cloud drop. The normal cloud model can be characterized by three numerical features: expectation Ex, entropy En, and hyper-entropy He. Ex reflects the central value of the qualitative concept, representing the average of cloud drops in U; En captures the uncertainty of the qualitative concept, where a larger En indicates greater fuzziness and randomness, making the concept more difficult to quantify; He is the entropy of entropy, representing the uncertainty associated with En itself. These three numerical features of the normal cloud model are illustrated in Figure 2.

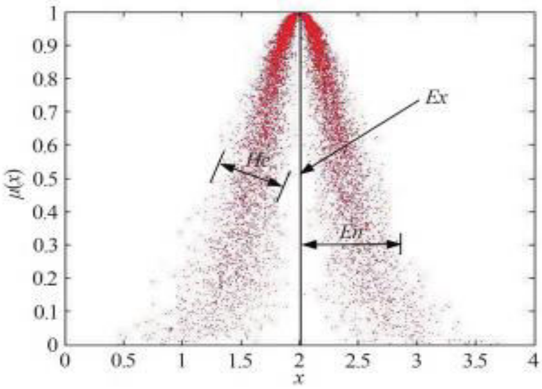

Figure 2. Three numerical characteristics of the normal cloud model

The computation of the cloud model relies on cloud generators, which are scientific tools that utilize computer algorithms to achieve the mapping transformation between qualitative fuzzy concepts and quantitative deterministic values. Based on their functions, cloud generators can be categorized into the Forward Cloud Generator (FCG) and the Backward Cloud Generator (BCG).The FCG represents the process of converting qualitative concepts into quantitative representations. Its inputs are the numerical characteristic values (Ex, En, He) representing the qualitative concept and the desired number of cloud drops n. The output is a cloud diagram containing n cloud drops, Drop(x_i, $\mu(x_i)$), indicating the precise positions within the cloud diagram space.Conversely, the BCG performs the inverse operation. It transforms precise data inputs into qualitative concepts by generating the numerical characteristic values (Ex, En, He) that reflect the overall cloud drop distribution.

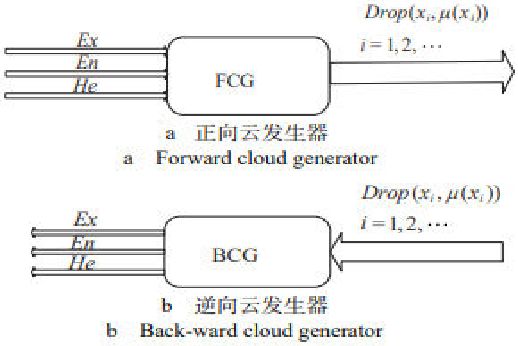

Figure 3 The FCG and BCG cloud generators are illustrated

By soliciting expert opinions and integrating the practical conditions of high-speed rail freight operations, the evaluation grades for safety indicators are divided into five risk levels: "Very Low Risk," "Low Risk," "Medium Risk," "High Risk," and "Very High Risk." These correspond to scoring intervals of [1, 2], [3, 4], [5, 6], [7, 8], and [9, 10], respectively, where a higher score indicates a greater risk associated with the evaluation indicator.

Based on cloud model theory, Formula (1) is used to determine the evaluation terms and parameters under bilateral constraints. That is, for each scoring interval [Xmin, Xmax], the corresponding standard cloud model numerical characteristics (Ex, En, He) can be derived using Formula (1). The classification of evaluation criteria levels and their corresponding cloud model parameters are shown in Table 2.

$$\begin{cases} Ex = (X_{\max} + X_{\min}) / 2 \\ En = (X_{\max} - X_{\min}) / 6 \\ He = k \end{cases} \quad (1)$$

Where:*Xmin* and *Xmax* represent the lower and upper limits of the scoring interval for the evaluation indicator, respectively;*k* is a constant that can be adjusted based on the fuzziness of the variable, with a value of 0.05 assigned in this context.

Table 2. Classification of Evaluation Criteria Levels and Corresponding Cloud Model Parameters

valuation Criteria	**Grade Classification**	**Cloud Model Characteristic Parameters**
Extremely Low Risk	[1, 3)	(1.5, 0.1667, 0.05)
Relatively Low Risk	[3, 5)	(3.5, 0.1667, 0.05)
Medium Risk	[5, 7)	(5.5, 0.1667, 0.05)
Relatively High Risk	[7, 9)	(7.5, 0.1667, 0.05)
Extremely High Risk	[9, 10]	(9.5, 0.1667, 0.05)

The cloud model characteristic parameters obtained from Table 2 are input into the pre-programmed system, with the number of cloud drops set to 3000. Standard cloud maps for each evaluation grade are then generated. The resulting standard cloud maps for the evaluation indicators are shown in Figure 4.

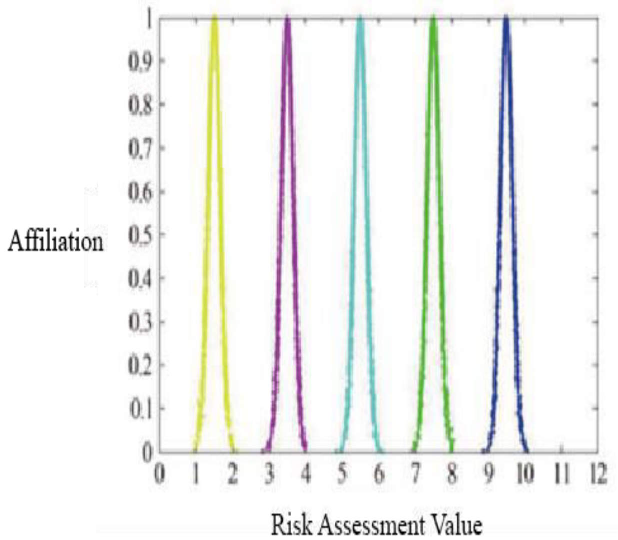

Figure 4. Standard cloud map of evaluation indicators

3.3 High-Speed Rail Freight Safety Evaluation Model Based on AHP-Cloud Model**

For a specific high-speed rail freight route to be evaluated, a panel of *n* experts—including railway bureau transport supervisors, rail freight domain specialists, and high-speed rail safety inspectors—are invited to score each secondary risk evaluation indicator (risk item) of the dedicated line. The scoring is based on the route's safety evaluation reports, risk assessment documents, and on-site inspection results. Scores range from 1 to 10, with higher values indicating greater risk. Let the set of expert scores be denoted as {P_1, P_2, …, P_k, …, P_n}, where P_k represents the subjective score assigned by the k-th expert (k = 1, 2, …, n) to a particular secondary risk indicator. The specific steps for conducting the AHP-Cloud Model-based safety evaluation of high-speed rail freight are as follows:

Step 1: Calculate the cloud digital characteristic parameters of secondary evaluation indicators.**

The expert scores for each secondary indicator are converted into cloud model digital characteristic parameters using the backward cloud generator. Equation (2) is applied to compute the corresponding cloud parameters (Ex_i, En_i, He_i) for each indicator.

$$\begin{cases} Ex_i == \frac{1}{n}\sum_{k=1}^{n} P_k \\ En_i = \sqrt{\frac{\pi}{2}} \times \frac{1}{n}\sum_{k=1}^{n} |P_k - Ex_i| \\ He_i = \sqrt{|S_i^2 - En_i^2|} \\ S_i^2 = \frac{1}{n-1}\sum_{k=1}^{n} (P_k - Ex_i)^2 \end{cases} \quad (2)$$

Step 2: Calculate the cloud digital characteristic parameters of primary evaluation indicators.

The comprehensive computation for higher-level evaluation indicators involves synthesizing subordinate concepts into a broader conceptual framework. Specifically, two or more secondary evaluation indicator cloud models are integrated into a more generalized cloud model. During this synthesis process, the weights of the secondary evaluation indicators must be considered. Equation (3) is used to transform the cloud models of the secondary indicators into a comprehensive cloud model for the primary evaluation indicator:

$$(Ex, En, He) = \left(\sum_{i=1}^{m} w_i Ex_i, \sqrt{\sum_{i=1}^{m} (w_i En_i)^2}, \sqrt{\sum_{i=1}^{m} (w_i He_i)^2}\right)$$

where m represents the number of secondary evaluation indicators under each primary indicator, and w_i denotes the weight value of each secondary indicator.

Step 3: Determine the comprehensive evaluation cloud model.

Using Equation (3), the digital characteristic parameters of the primary evaluation indicator cloud models and their respective weights are combined to calculate the comprehensive cloud model parameters for high-speed rail freight transportation. The resulting cloud diagram is compared with the standard cloud diagram to determine the risk level of the high-speed rail freight operation:

$$(Ex \ , En \ , He \ ) = \left(\sum_{j=1}^{p} w_j Ex_j, \sqrt{\sum_{j=1}^{p} (w_j En_j)^2}, \sqrt{\sum_{j=1}^{p} (w_j He_j)^2}\right)$$

where p represents the number of primary indicators, and w_j denotes the weight of each primary indicator.

IV. CASE STUDY

This study selects the high-speed rail express operation department of a first-class passenger station as the research object. The station is primarily responsible for passenger and express transport services connecting the three northeastern provinces and Beijing. Through field investigations and surveys, the data required for evaluation were collected. The Analytic Hierarchy Process (AHP) and expert scoring method were employed to determine the weights and characteristic values of the indicators. Finally, the established evaluation model and indicator system were applied to comprehensively assess the risk status of high-speed rail freight transportation.

4.1 Calculation of Weights Using AHP

The evaluation factors in this study are primarily qualitative, with limited quantitative factors. Furthermore, the risk evaluation factors for high-speed rail freight are structured hierarchically. Therefore, a combination of research and expert scoring was used to quantitatively analyze the factors influencing high-speed rail freight safety, deriving the characteristic values for each factor. Based on expert opinions and the actual conditions of high-speed rail freight operations, the safety indicators were classified into five risk levels: "Very Low Risk," "Low Risk," "Medium Risk," "High Risk," and "Very High Risk." The corresponding scoring intervals are [1, 2], [3, 4], [5, 6], [7, 8], and [9, 10], respectively, with higher scores indicating greater risk.

Judgment matrices were constructed using the 1–9 scale method to enhance comparison accuracy. First, the weights of the first-level indicators were established, normalized, and subjected to consistency checks. The same method was then applied to calculate the weights of the second-level indicators under each first-level indicator. The results are shown in Table 3.

Item	Eigenvector	Weight Value	Maximum Eigenvalue	CI Value
Operational Standardization	1.819	45.483%	4.010	0.003
Equipment and Facility Reliability	1.052	26.301%		
Personnel Compliance	0.564	14.108%		
Safety Management Completeness	0.564	14.108%		

Generally, a smaller Consistency Ratio (CR) value indicates better consistency of the judgment matrix. Typically, if the CR value is less than 0.1, the judgment matrix is considered to pass the consistency test. If the CR value exceeds 0.1, it indicates inconsistency, and the judgment matrix should be appropriately adjusted before reanalysis.

In this study, for the 4th-order judgment matrix, the calculated Consistency Index (CI) is 0.003. Referring to the table of Random Index (RI) values, the corresponding RI value is 0.890. Thus, the CR value is calculated as 0.004 (0.003 / 0.890), which is less than 0.1. This indicates that the judgment matrix in this study satisfies the consistency test, and the calculated weights are consistent, as shown in Table 4. Subsequently, the weights of the secondary indicators in the high-speed rail freight risk evaluation index system were calculated and normalized. The results are as follows:

Table 4. Summary of Consistency Check Results

Maximum Eigenvalue	CI Value	RI Value	CR Value	Consistency Check Result
4.010	0.003	0.890	0.004	Pass

Table 5 AHP Hierarchical Analysis Results

Item	Eigenvector	Weight Value	Maximum Eigenvalue	CI Value
Machine Security Inspection	1.619	32.376%	5.098	0.024
Real-name Consignment	1.201	24.022%		
Cargo Sorting	1.043	20.864%		
Stacking/Palletizing	0.648	12.958%		
Package Opening Inspection	0.489	9.781%		

Table 6. AHP Hierarchical Analysis Results

Item	Eigenvector	Weight Value	Maximum Eigenvalue	CI Value
Security Equipment, etc.	0.510	16.984%	3.018	0.009

In/Outbound Channels for Small Parcels	1.329	44.286%		
Temporary Storage Area for Small Parcels	1.162	38.730%		

Table 7 AHP Hierarchical Analysis Results

Item	Eigenvector	Weight Value	Maximum Eigenvalue	CI Value
Professional Competence	0.936	31.190%	3.054	0.027
Psychological Quality	0.593	19.762%		
Labor Discipline	1.471	49.048%		

Table 8 AHP Hierarchical Analysis Results

Item	Eigenvector	Weight Value	Maximum Eigenvalue	CI Value
Dual-prevention Mechanism	1.617	53.897%	3.009	0.005
Three-in-one System	0.892	29.725%		
Safety Education	0.491	16.377%		

4.2 Cloud Model Calculation and Cloud Map Generation

Based on the AHP weight calculation results, the three parameters (Ex, En, He) of the cloud models for each first-level indicator were determined as follows: Operational Standardization (4.77, 0.30, 0.26), Equipment and Facility Reliability (4.56, 0.36, 0.30), Personnel Compliance (2.5, 0.27, 0.20), and Safety Management Completeness (2.4, 0.30, 0.28). Using MATLAB software, evaluation cloud maps for the four first-level indicators were generated and compared with the standard cloud maps, with the comparative results presented in the following figures.

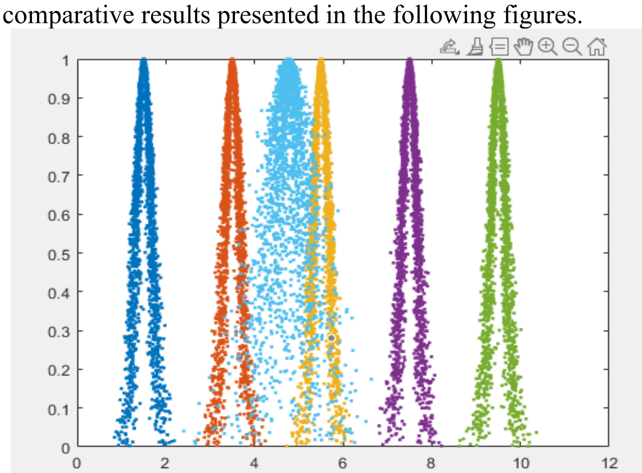

Figure 4. Cloud Map of Operational Standardization

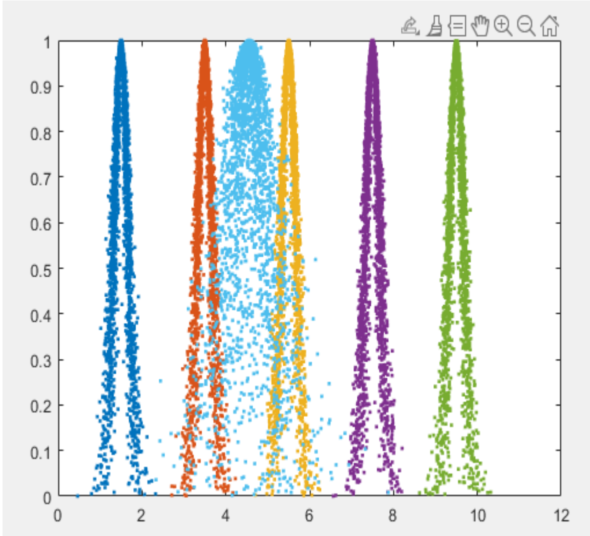

Figure 5. Cloud Map of Equipment and Facility Reliability

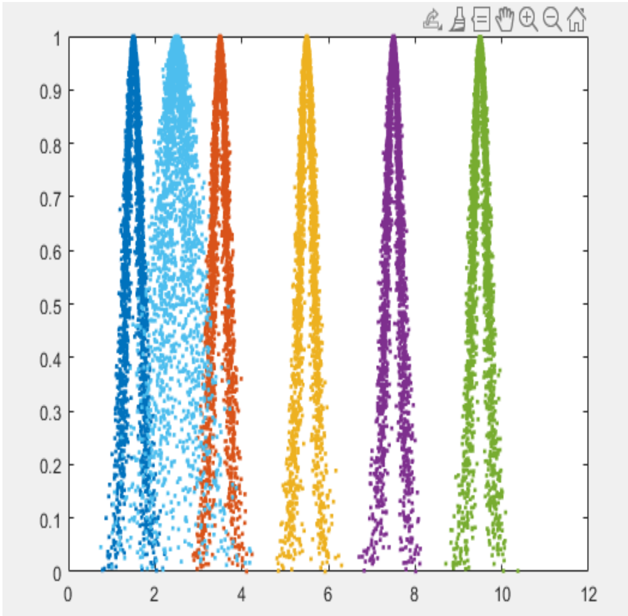

Figure 6. Cloud Map of Personnel Compliance

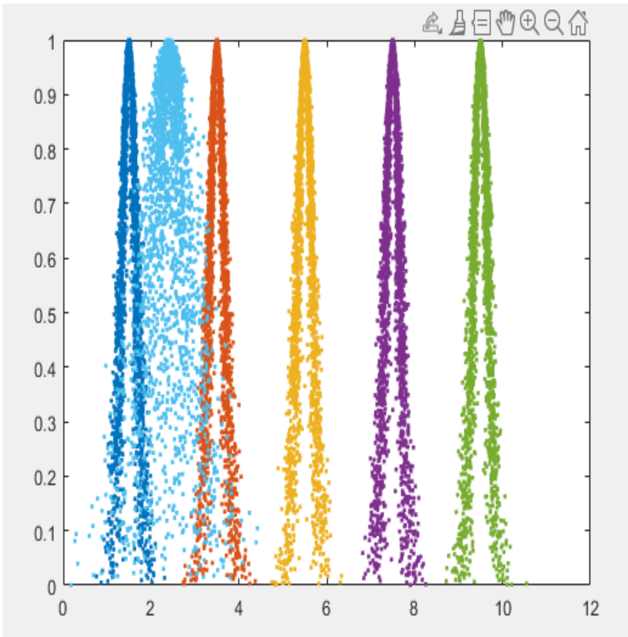

Figure 7. Cloud Map of Safety Management Completeness

By integrating the characteristic parameters of the four first-level evaluation indicator cloud models and applying Formula (3), the comprehensive cloud model parameters for the risk assessment of the high-speed rail express freight department at a first-class passenger station were calculated as R = (3.34, 0.28, 0.30). The comprehensive risk evaluation cloud model is illustrated in Figure 8.

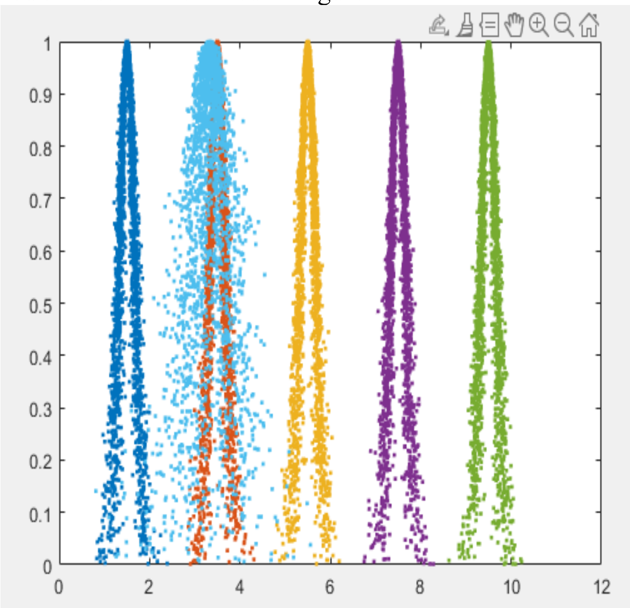

Figure 8. Comprehensive Evaluation Cloud Model Diagram

4.3 Analysis of Simulation Results

(1) **Operational Standardization Risk**: The cloud model analysis yielded parameter values of (4.77, 0.30, 0.26), positioning the operational risk between "Low Risk" and "Medium Risk," with closer proximity to the medium-risk category (centered at 4.77 on a 10-point scale). Field investigations at the high-speed rail station revealed that approximately 40% of staff demonstrated insufficient familiarity with freight procedures, while 15% of operational records showed non-compliant practices.

(2) **Equipment and Facility Reliability**: With parameters of (4.56, 0.36, 0.30), the risk level falls between low and medium. This is primarily attributed to infrastructure limitations—over 80% of stations lack dedicated freight channels, and 70% lack standardized temporary storage areas, despite post-construction modifications meeting basic operational requirements.

(3) **Personnel Compliance**: The calculated parameters (2.5, 0.27, 0.20) indicate a risk level between "Very Low Risk" and "Low Risk," leaning toward the latter. Surveys showed that 85% of railway staff participated in regular competency training, and 92% passed quarterly operational assessments, reflecting strong professional discipline.

(4) **Safety Management Completeness**: Parameters of (2.4, 0.30, 0.28) place this category near the "Very Low Risk" threshold. Implementation data confirm that 95% of safety management systems incorporate dual-prevention mechanisms, while 88% of stations have established the "Three-in-One" safety framework as mandated by the 14th Five-Year Plan for Railway Safety.

(5) **Comprehensive Risk Assessment**: The integrated cloud model parameters R = (3.34, 0.28, 0.30) indicate an overall risk level approaching "Low Risk." Although 90% of risk indicators remain within acceptable ranges, approximately 5% of discrete cloud droplets fall within the medium-risk zone, highlighting specific areas requiring optimization in express freight services. These findings align with official safety evaluation reports and on-site inspection records, validating the model's practical applicability.

V. Conclusions and Discussion

5.1 Main Conclusions

The AHP-Cloud Model evaluation system developed in this study demonstrates effective applicability in high-speed rail freight risk assessment. Quantitative analysis reveals that the comprehensive risk level of the evaluated station registers at 3.34 (on a 10-point scale), falling within the "Low Risk" category. Specific indicator analysis shows:

Operational standardization presents the highest risk (4.77), with approximately 40% of operational personnel demonstrating insufficient process familiarity
Equipment and facility reliability follows at 4.56, primarily due to 80% of stations lacking dedicated freight channels
Personnel compliance (2.5) and safety management completeness (2.4) exhibit optimal performance, with over 85% of staff participating in regular training and 95% of safety systems incorporating dual-prevention mechanisms
The cloud model visualization successfully maps 90% of risk indicators within acceptable ranges, while identifying 5% of discrete risk points requiring prioritized intervention.

5.2 Discussion on Last-Mile Safety Challenges

While the overall risk assessment remains favorable, last-mile operations emerge as a critical vulnerability. Our data indicates:
Final delivery phases account for 35% of all operational incidents
60% of safety violations occur during terminal cargo handover procedures
Only 45% of stations have established standardized last-mile protocols
Three structural challenges contribute to these findings:
Infrastructure Gaps: 70% of stations lack integrated cargo-passenger flow separation systems
Procedural Limitations: Real-time monitoring covers only 50% of final delivery routes
Regulatory Fragmentation: 40% of last-mile operations fall outside railway safety jurisdiction

5.3 Recommendations

To address these challenges, we propose:
Implementing digital twin technologies to increase last-mile visibility by 60%
Developing unified safety standards for terminal operations by 2025
Establishing joint supervision mechanisms with logistics partners to cover 90% of final delivery routes
This study confirms that while high-speed rail freight maintains generally safe operations, targeted improvements in last-mile management could reduce overall incident rates by an estimated 25%. Future research should focus on dynamic risk modeling for real-time monitoring applications.

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