Coordination Evaluation Research of Railway Collection and Distribution System in Port Areas Based on Cloud Model

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Abstract: The railway is of great significance for port cargo to achieve collection and distribution. It is necessary to evaluate the coordination of the railway collection and distribution system scientifically in port areas. Based on the research that analyses factors that affecting the coordination of railway collection and distribution system in port areas and constructs a comprehensive evaluation indicator system, this paper innovates a comprehensive evaluation model suitable for studies of the coordination of railway collection and distribution system in port areas by combining the cloud model algorithm with the traditional expert scoring method. Then, this paper will verify the applicability and operability of the model we proposed by representing a case study of the coordination of the railway collection and distribution system in Caofeidian Port Area.

1. Introduction

The Railway Collection and Distribution System(RCDS) is an important part of the port collection and distribution system. In port areas, improving the coordination of the RCDS is beneficial to collecting and distributing cargos smoothly and rapidly. Therefore, in port areas, it is necessary to evaluate the coordination of the RCDS scientifically and reasonably [1].

The factors affecting the coordination of the RCDS in port areas can be analysed qualitatively and quantitatively. Meanwhile, given that the port railway has less historical data, the evaluation result can be only determined by experts' comments at most of the time. Therefore, the fuzziness and randomness inside coordination itself and the uncertainty of experts' experience should be considered in the research process. However, while processing experts' comments, the cloud model can give a feedback that could present the uncertainty in the coordination evaluation and both the fuzziness and the randomness in human cognitive process [2]. Because of those reasons listed above, in port areas, the cloud-model-based RCDS coordination evaluation model can improve the reliability of the evaluation results effectively.

2. Analysis of influencing factors

In port areas, since the RCDS's coordination is determined by equipment, production organization, operation management and capacity coordination determined by railway transportation and port loading-unloading operation, this paper considers the influencing factors from the above listed aspects.

2.1 Equipment coordination influencing factors

The focus of equipment coordination is to achieve the adaptability of capacity, the matching of technical standards, the rationality of the layout and the convenience of operation between the port station and the link railway.

(1) Railway routes technical standards matching level: This indicator directly affects whether the railway transportation procedure can be carried out in an orderly manner.

(2) Convenience of port railway: The better this indicator is, the closer the relationship between the port area and the economic hinterland is.

(3) Automation of loading-unloading equipment: The higher this indicator is, the higher the loading-unloading efficiency is.

(4) Working normalization of loading-unloading equipment: This indicator reflects the utilization of loading-unloading equipment.

(5) Standardization of rolling stock: Increasing this indicator can improve transportation efficiency and ensure railway transport capacity.

2.2 Production organization coordination influencing factors

The production organization of railway transportation and internal loading-unloading operations in port areas will directly affect the coordination of railway and port work. Therefore, this paper selects influencing factors from aspects of railway-to-port plan convertibility, freight wagons detention time in port, proportion of freight wagons loading-unloading time, and average storage days of cargo in port.

(1) Railway-to-port plan convertibility: The better this indicator is, the smoother the docking of railway and port operation planning is.

(2) Freight wagons detention time in port: This indicator determines the realization of railway transportation planning.

(3) Proportion of freight wagons loading-unloading time: The higher this indicator is, the more uncoordinated the port operation planning is.

(4) Average storage days of cargo in port: This indicator reflects the coordination of the connection of railway transportation planning and port operation planning.

2.3 Operation management coordination influencing factors

The operational management coordination represents the coordination degree of managements in different departments during freight transportation. Thus, influencing factors of unity of transportation command, rationality of administrative system, and information resource sharing degree were selected.

(1) Unity of transportation command: This indicator measures the degree of coordination among various management departments involved in the RCDS in port areas.

(2) Rationality of administrative system: The scientific administrative system reduces the difficulty of coordination among the various management subjects.

(3) Information resource sharing degree: The better this indicator is, the better the exchange of information and the coordination among various management departments are.

2.4 Capacity coordination influencing factors

The capacity coordination directly displays the coordination of the RCDS in port areas. Specifically, the capacity coordination includes two aspects: the capacity coordination between railways and ports, and the capacity coordination between railway routes and stations.

In this paper, the capacity coordination between railways and ports was calculated by railway network capacity utilization, collection-requirement capacity adaptability in port areas, distribution-requirement capacity adaptability in port areas, transportation and loading-unloading capacity matching degree, and transportation and storage capacity matching degree. The capacity coordination between railway routes and stations was determined by railway routes and stations through capacity matching degree.

2.5 The indicator system of coordination evaluation

Following the principles of clear purpose and level, this paper divides the evaluation indicator system into target layer, criterion layer and indicator layer. The indicators of the criterion layer are expressed as Ai, (i = 1, 2, 3, 4) and those of the indicator layer are expressed as Aij (i = 1, 2, 3, 4, j = 1, 2, 3, 4, 5, 6), as shown in Table 1.

Table 1 The Coordination Evaluation Indicator System.

Target layer	Criterion layer	Indicator layer
Coordination of the RCDS in port areas A	Capacity coordination A1	Collection-requirement capacity adaptability in port areas A11
		Distribution-requirement capacity adaptability in port areas A12
		Railway network capacity utilization A13
		Railway stations and routes through capacity matching degree A14
		Transportation and loading-unloading capacity matching degree A15
		Transportation and storage capacity matching degree A16
	Equipment coordination A2	Railway routes technical standards matching level A21
		Convenience of port railway A22
		Automation of Loading-unloading equipment A23
		Working normalization of loading-unloading equipment A24
		Standardization of rolling stock A25
	Production organization coordination A3	Freight wagons detention time in port A31
		Proportion of freight wagons loading-unloading time A32
		Average storage days of cargo in port A33
		Railway-to-port plan convertibility A34
	Operation management coordination A4	Unity of transportation command A41
		Rationality of administrative system A42
		Information resource sharing degree A43

3. Cloud model algorithm

3.1 The numerical characteristics of cloud model

Since expectation (Ex), entropy (En), hyper entropy (He) can describe overall characteristic of a qualitative concept, the cloud model is usually represented by $C(Ex, En, He)$. Based on these three numerical characteristics, a cloud graph composed of many cloud drops can be vividly depicted [3].

Ex is the most representative and typical sample of the qualitative concept. En is used to measure the uncertainty of qualitative concepts. The higher the En is, the more the concept tends to be fuzzy. He is used to measure the uncertainty of En, which indicates the degree of dispersion of cloud drops. The higher He is, the larger the dispersion degree of cloud drops is.

3.2 Cloud generator algorithm

The forward cloud generator (FCG) realizes the transformation of a qualitative concept to multiple drops through the three numerical characters (Ex, En, He) by the following steps:

(1) Generating a normally distributed random number $En' \sim N(En, He^2)$;

(2) Generating a normally distributed random number $x_i \sim N(Ex, En'^2)$;

(3) Defining $y(x_i)$ as the certainty degree that x_i belongs to the qualitative concept;

(4) Calculating $y_i = \exp(-\frac{(x_i - Ex)^2}{2(En')^2})$;

(5) (x_i, y_i) is a cloud drop;

(6) Repeating above steps until you have N cloud drops.

The backward cloud generator (BCG) can transform a certain amount of cloud drops into three numerical characteristics (Ex, En, He) to represent a qualitative concept. In this paper, the BCG uses an improved algorithm that does not require certainty degree information. The algorithm is as follows:

(1) Calculating the overall sample mean of x_i by $\bar{X} = \sum_{i=1}^{n} x_i / n$;

(2) Calculating expectation by $Ex = \bar{X}$;

(3) Calculating entropy by $En = \sqrt{\pi/2} \times \frac{1}{n} \sum_{i=1}^{n} |x_i - Ex|$;

(4) Calculating sample variance by $S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{X})^2$;

(5) If $S^2 - En^2 \geq 0$, then go to step (7), otherwise go to step (6);

(6) Deleting the nearest 1% of the sample points in the current sample from Ex;

(7) Deleting $\sum_{i=1}^{n\times 0.01} sort(|x_i - Ex|), n = 0.99 \times n$, then turn to step (4);

(8) Calculating hyper entropy by $He = \sqrt{S^2 - En^2}$.

3.3 Calculate Integrated cloud model

The essence of the integrated cloud model is the concept generalization, that is, the integration of two or more language values of the same type into a more general concept language value [4]. Assume that Ex, En, and He are the numerical characteristics of the integrated cloud. Ex_m, En_m, and He_m are the numerical characteristics of the sub-cloud model. Then:

$$Ex = \frac{Ex_1En_1 + Ex_2En_2 + \cdots + Ex_mEn_m}{En_1 + En_2 + \cdots + En_m} \quad (1)$$

$$En = En_1 + En_2 + \cdots + En_m \quad (2)$$

$$He = \frac{He_1En_1 + He_2En_2 + \cdots + He_mEn_m}{En_1 + En_2 + \cdots + En_m} \quad (3)$$

4. Coordination Evaluation Model Based on Cloud Model

4.1 Determine the evaluation set

Based on the definition of five-layer normal cloud, this paper divides the coordination state of the RCDS in port areas into five levels: wonderful coordination C1, well coordination C2, basic coordination C3, basic incoordination C4 and serious incoordination C5. The cloud models are C1(1.0, 0.1031, 0.013), C2(0.691, 0.064, 0.008), C3(0.5, 0.039, 0.005), C4(0.309, 0.064, 0.008), C5(0, 0.1031, 0.013), and the subgraph (a) in Figure 1 is the cloud graph [5].

4.2 Determine the evaluation indicator cloud weight

In this paper, the indicator weight is represented by the cloud weight method. Ex is the weight of the indicator. En and He are parameters used to soften the weight of indicator.

Firstly, experts and scholars in this profession are invited to give scores according to the importance of the lower level indicators relative to the upper level indicator. Then, the cloud generator processes expert scores to obtain the corresponding cloud weight and cloud graphs. Finally, this paper judges the rationality of expert scoring result by dispersion and aggregation of cloud drops in cloud graphs. According to the "expert scoring-results collection-cloud graphs judgment-feedback-expert re-scoring" process, it minimizes the subjectivity of expert scoring and maximizes the accuracy and scientific of evaluation results.

In this process, the cloud graph is constantly improved, indicating that the concept is gradually formed. In the end, cloud weights of indicator are normalized by the $W_{ij} = W_{ij}/(\sum_{j=1}^{n} w_{ij})$ formula.

4.3 Determining the actual cloud model and coordination evaluation level

For each influencing factor indicator, experts give the minimum and maximum score. The BCG processes the expert scores to obtain the minimum and maximum value cloud model. Then this paper calculates the actual cloud model by integrating the minimum and maximum value cloud model. Based on the cloud weight W_i of the indicator i and the actual cloud model RC_i, the cloud model of upper level indicator can be obtained by the formula $RC = \sum_{i=1}^{N} RC_i \times W_i$.

Finally, compare cloud graph of indicator with cloud graphs of evaluation set (C1, C2, C3, C4, C5) and determine the coordination level of indicator.

5. Case Analysis

Taking Caofeidian Port Area as an example, it invites ten experts to participate in scoring. According to the previous method, the comprehensive cloud model of the RCDS in Caofeidian Port Area was A(0.8541,0.2266,0.0273). The cloud model and the cloud weight of each indicator in the criteria layer and the indicator layer were calculated, as shown in Table 2.

Table 2 Cloud model solution result

Criteria layer(cloud model/cloud weight)	Indicator layer(cloud model/cloud weight)
A1(0.8666, 0.1802, 0.0293) /(0.2462, 0.0652, 0.0054)	A11(0.9022, 0.0912, 0.0121)/(0.1793, 0.0201, 0.0099)
	A12(0.8133, 0.1053, 0.0243)/(0.1616, 0.0251, 0.0069)
	A13(0.8736, 0.1253, 0.0128)/(0.1283, 0.0501, 0.0036)
	A14(0.8700, 0.0802, 0.0158)/(0.1659, 0.0401, 0.0027)
	A15(0.9320, 0.0622, 0.0106)/(0.1833, 0.0071, 0.0024)
	A16(0.8052, 0.0521, 0.0105)/(0.1815, 0.0381, 0.0033)
A2(0.8703, 0.1033, 0.0205) /(0.2766, 0.0501, 0.0052)	A21(0.8933, 0.0398, 0.0092)/(0.2118, 0.0040, 0.0006)
	A22(0.8500, 0.0602, 0.0124)/(0.2136, 0.0205, 0.0030)
	A23(0.8740, 0.0501, 0.0114)/(0.1737, 0.0326, 0.0085)
	A24(0.9377, 0.0411, 0.0089)/(0.2160, 0.0077, 0.0028)
	A25(0.7845, 0.1103, 0.0034)/(0.1850, 0.0302, 0.0049)
A3(0.8837, 0.1499, 0.0201) /(0.2523, 0.0301, 0.0024)	A31(0.9178, 0.0441, 0.0099)/(0.2802, 0.0401, 0.0059)
	A32(0.9323, 0.0491, 0.0176)/(0.2457, 0.0451, 0.0060)
	A33(0.8600, 0.0702, 0.0121)/(0.1613, 0.0211, 0.0019)
	A34(0.8272, 0.0632, 0.0103)/(0.3128, 0.0501, 0.0036)
A4(0.7875, 0.1354, 0.0243) /(0.2249, 0.0602, 0.0029)	A41(0.8070, 0.1073, 0.0183)/(0.3587, 0.0301, 0.0034)
	A42(0.7530, 0.1003, 0.0182)/(0.2611, 0.0361, 0.0060)
	A43(0.7927, 0.1293, 0.0250)/(0.3802, 0.0221, 0.0060)

The subgraph (b) in Figure 1 is the comprehensive cloud model of the coordination state of the RCDS in Caofeidian Port Area. The coordination level lies between well coordination and wonderful coordination. The dispersion of cloud drops is low, indicating that the experts have small differences and recognitions toward the evaluation results with high confidence. The large entropy shows that the degree of coordination of the RCDS in Caofeidian Port Area has strong fuzzy and uncertainty, and it may vary with influencing factors.

The subgraph (c), (d), (e) and (f) in Figure 1 are the cloud graphs of various criteria indicators. According to cloud graphs, it can be visually observed that the four criterion indicators have the highest subordinate degree lying between well coordination and wonderful coordination, and overall coordination is good. The cloud drops are central distributed, meaning the expert opinions are uniform.

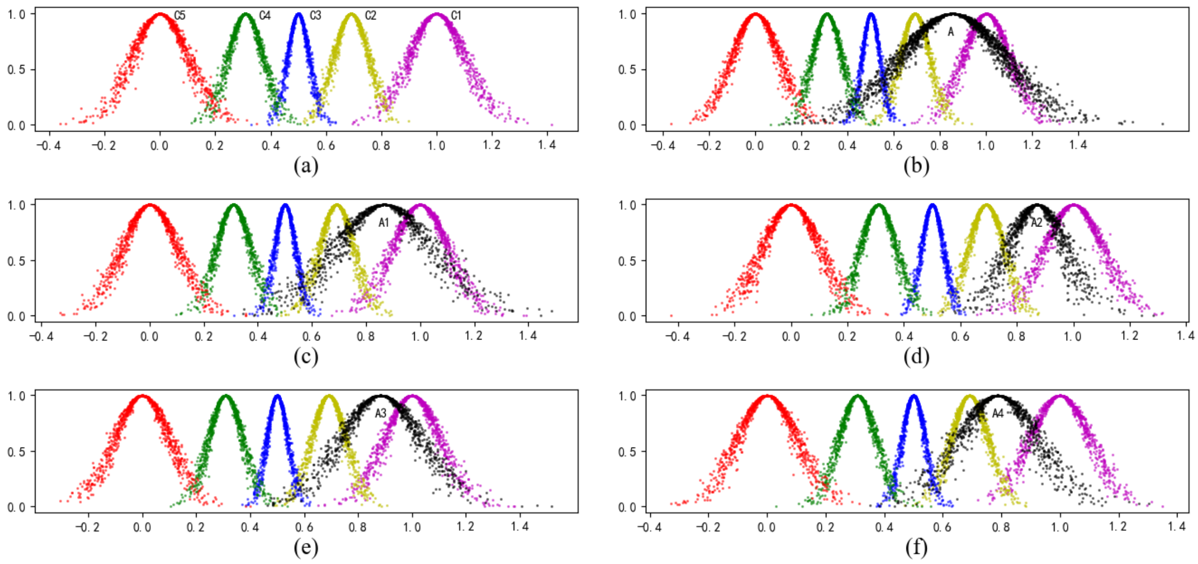

Fig. 1 Coordination evaluation cloud graphs

6. Summary

Through the analysis of the coordination of the RCDS in port areas, this paper constructs the coordination evaluation indicator system for the RCDS in port areas, including four criterion level indicators and eighteen indicator level indicators. By introducing cloud model, which has good processing effect on fuzzy and uncertainty, this paper reduces the subjectivity of expert scoring and improves the reliability of coordination evaluation. The feasibility of the method is verified by taking Caofeidian Port Area. The coordination evaluation result of the RCDS in Caofeidian Port Area shows that the coordination of the RCDS is good but has strong fuzzy and uncertainty which implies the coordination could be easily destroyed in near future.

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