Research on Profit Distribution of Shipping Alliance Based on Cloud TOPSIS-AT Solution Model

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Abstract. The fairness and efficiency of the profit distribution scheme are important factors to ensure the stable operation of the shipping alliance. However, the limitations of the communication structure in the shipping alliance and the differences in the commitment of each member enterprise to various factors in the alliance pose challenges to the formulation of the alliance's profit distribution. To solve this problem more reasonably, first of all, this paper summarizes the influencing factors of profit distribution in shipping alliances, explains each factor and gives the evaluation method. Then, considering the limitation of the communication structure of the shipping alliance, this paper takes the AT solution as the basic model of profit distribution, and then considers the commitment of each enterprise in the alliance, introduces the improved Cloud Gravity method based on TOPSIS method to improve the traditional AT solution model, and proposes the Cloud TOPSIS-AT solution model. Through the example analysis, the profit distribution schemes obtained by the cloud TOPSIS-AT solution model, the Shapley value method, and the traditional AT solution model are compared. The results show that the Cloud TOPSIS-AT solution model has stronger applicability when the shipping alliance has the limitation of communication structure and the factors of each enterprise in the alliance are different, which can provide a more scientific and reasonable solution for the profit distribution of the shipping alliance. This study has practical significance for promoting the further healthy development of shipping alliances and the shipping market economy.

Keywords: Shipping Alliance; Profit Distribution; AT; Cloud TOPSIS.

1 Introduction

The shipping alliance is a collaborative organization composed of multiple shipping companies. The purpose is to achieve complementary advantages and maximize profits among member enterprises by sharing ships, resources and networks. Alliance members usually sign agreements to clarify their respective responsibilities and profit distribution methods, work together to operate routes and enhance market competitiveness. According to the International Maritime Organization, shipping alliances have flourished over the past decade, with 19 shipping alliances covering most of the world's shipping markets by 2022. These alliances include large alliances in Europe and Asia, such as “2M”, “Ocean Alliance”, “THE Alliance”, and “OCEAN”, “THE Alliance” in the United States. However, the problem of profit distribution among shipping alliance members has always been one of the key problems restricting the healthy development of the alliance. Therefore, formulating a reasonable income distribution model and designing a scientific and reasonable profit distribution plan to ensure the sustainability and stability of alliance cooperation has always been the core issue of academic and practical circles.

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Domestic and foreign scholars mainly use mathematical optimization, economic principles and game theory to study the distribution of cooperative profits between different enterprises. Wang[1] studied the benefit-sharing problem of shipping alliance by using cooperative game theory and proposed an improved Shapley model to analyze the profit distribution scheme of shipping alliance. Bin[2] used the modified Shapley value method to analyze the profit distribution of liner alliance from the perspective of both supply and demand. In order to solve the problem of income distribution in strategic alliances, Huang[3] added a series of variables to the Shapley value method, which is more in line with the long-term development of the alliance. Meng[4] studied the profit allocation mechanism under the capacity sharing of shipping alliance from the characteristics of blockchain. Chang[5] used Shapley value model modified by AHP and Entropy weight method solves the shortcomings of the traditional Shapley value model and promotes the stable development of shipping alliance.

At present, the research on the profit of shipping alliance at home and abroad mainly focuses on the construction and optimization of the model. The research on cooperative countermeasures is mainly based on the basic assumption that any sub-alliance can be freely aligned, and less consideration is given to the actual impact of communication structure constraints among alliance members on profit distribution. In fact, the business form of shipping market is complex, and the cooperation between shipping alliances is often affected by the limitation of communication structure, that is, due to various reasons, sub-alliance cannot form a direct alliance. Considering the limitation of communication structure, it is helpful to more accurately determine the status difference and corresponding profit distribution among the members of the alliance, so as to promote the stable and efficient operation of the alliance. Yang[6] studied the cooperative allocation problem of restricted coalitions and gave a solution to the Average Tree (AT solution) which is more suitable for the communication structure game. Wang[7] proposed a revenue distribution method combining graph game and Cloud theory for dynamic alliances with communication structure constraints. Herings[8] proposed the average tree solution for cooperative games with communication structure, and proved that when the game has a complete communication structure, the average tree solution is equal to the Shapley value. Yang[9] proposed an AT solution profit distribution method for cooperative games with a restricted communication structure, which is more reasonable than Shapley value. Secondly, when studying the factors affecting the profit distribution of shipping alliances, the existing literature usually fails to fully consider the characteristics of alliance profit distribution. Comprehensive consideration of various influencing factors helps to more fully reflect the cooperation relationship and profit distribution among members of the shipping alliance. Li[10] added four correction criteria to Shapley value and obtained the optimal profit distribution scheme of the urban joint distribution alliance. Rusinov[11] proposed that the benefits of shipping alliances are related to many factors such as the degree of collaboration between enterprises, cost performance and enterprise size. In order to solve the problem of partner selection and profit distribution, Fahimullah[12] established a profit distribution model based on Shapley value. Zhang[13] determined the correction value of income distribution by the Cloud Gravity method modified by TOPSIS method, which made the income distribution of port alliance more fair and more reasonable.

In summary, it is of great practical significance and academic value to design a profit distribution mechanism that takes into account the constraints of the communication structure and the combined effects of various factors in the shipping alliance. Based on this, this paper proposes a profit distribution scheme of Cloud TOPSIS-AT solution model, aiming to better analyze the profit distribution mechanism of shipping alliance, provide a reference for the actual and effective operation of shipping alliance, and promote the healthy development of shipping market economy.

2 Influential factors and evaluation methods of shipping alliance profit distribution

Considering the influencing factors of the profit distribution of the shipping alliance can help to establish a good cooperative relationship and ensure the sustainable development of the alliance. Combined with the analysis of the influencing factors of profit distribution of shipping alliance by experts and scholars, it can be seen that when constructing the profit distribution model, the factors such as resource input, professional ability contribution, effort level, risk taking and logistics service quality can be considered more comprehensively.

2.1 Resources input

(1) Capital investment. Shipping alliance involves shared resources and cooperation activities. To a large extent, enterprises with more capital investment are likely to obtain a higher profit share.

(2) Equipment input. Shipping enterprises provide more capacity and high-quality services by investing in equipment and updating equipment, and then get more freight volume and profit share.

(3) Personnel input. Shipping companies can improve the quality of transportation services and increase the level of profits by investing in various human resources in the business process.

2.2 Professional ability contribution

(1) Cargo traffic volume. Shipping alliance enterprises with advanced ships and ship leasing can provide better transportation capacity for the alliance, and make a greater contribution to the overall operation and profit of the shipping alliance.

(2) Shipping management capabilities. Shipping companies may be able to provide high-quality shipping management services to obtain more profits by having professional ship management, route planning, shipping operations and other capabilities.

(3) Marketing ability. Shipping enterprises with good marketing and business development and other capabilities can improve the market competitiveness and overall profit of the alliance.

2.3 Level of effort

(1) Low-carbon efforts. The low-carbon level of enterprises can be regarded as a contribution to the sustainable development of the alliance. The greater the contribution of enterprises to environmental protection, the greater the input cost, so more profits should be allocated.

(2) Innovation efforts. Enterprises with higher innovation ability can often achieve higher contribution in operational efficiency, cost control and other aspects in the operation process and obtain a corresponding higher profit share.

(3) Efforts to cooperate with the alliance. In the shipping alliance cooperation, it needs the joint efforts of all member units to truly realize the maximum value and benefit of the alliance cooperation.

2.4 Risk-taking

(1) Market competition risk. The potential risks faced by alliance members caused by market competition pressure and uncertainty will affect the profit distribution ratio of alliance members.

(2) Cooperation risk. The potential risks caused by the unsmooth cooperation relationship between the members of the alliance or the implementation of the cooperation agreement lead to the breakdown of the cooperation relationship.

(3) Technical risk. The potential technical risks related to shipping business caused by technical failure, data security, technology updates and other factors may have an indirect impact on the profit distribution of the shipping alliance.

(4) Operational risk. The uncertain factors such as market fluctuations, changes in policies and regulations, accidents and other risks that may lead to the failure to achieve business objectives in the business process will affect the effectiveness of the alliance.

2.5 Logistics service quality

(1) On-time delivery rate. Shipping alliance member enterprises can improve customer satisfaction by optimizing cargo loading, unloading and transportation processes and shortening the transportation time of goods.

(2) Freight loss rate. The level of freight loss rate directly affects the business operation of shipping alliance. Lower freight loss rate usually means higher transportation quality.

(3) Information accuracy. Shipping alliance member enterprises provide timely and accurate transportation information, which can improve customers' controllability and transparency of cargo transportation and improve logistics service quality.

(4) Customer complaint rate. Shipping alliance member enterprises to maintain good communication and cooperation with customers, and timely solve complaints, can enhance customer satisfaction and loyalty.

(5) Order processing timeliness rate. Short-term order processing helps to improve customer satisfaction and operational efficiency, and brings more profits to the alliance.

Five experts in the shipping field were invited to use the five-level scale method to score the above-mentioned influencing factors of each shipping enterprise in the alliance, which were recorded as $E_{x_1}^{1},\cdots,E_{x_5}^{1}$ to $E_{x_1}^{18},\cdots,E_{x_5}^{18}$.

3 Improved Cloud TOPSIS-AT solution profit distribution model

3.1 Traditional AT solution model

In the actual shipping alliance, due to the influence of various factors such as politics, geography, competition, and technology, the cooperation between the alliances often cannot directly establish the free alliance model shown in Figure 1, but there is a communication structure limit shown in Figure 2. For example, in a shipping alliance, freight companies and shipping companies may need to connect through port operators to achieve the alliance. In this case, the first two have the limitation of communication structure, which also leads to the higher status of port operation enterprises should get more profits.

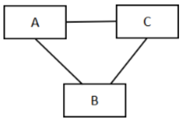

Fig.1. Inter-alliance relationship in free alliance.

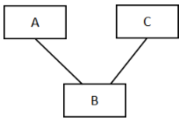

Fig.2. Inter-alliance relationship considering the limitation of communication structure.

In view of the limitation of the communication structure of the shipping alliance, this paper proposes a traditional AT solution profit distribution model, as follows.

The cooperative game of shipping alliance with communication structure restriction, that is, the graph game, can be expressed as (N,v,L), where $N=\{1,2,\cdots,n\}$ is the set of shipping alliance member enterprises, $v:2^N \to R$ is the profit function, and in the definition graph (N,L), not all enterprises cooperate. If (1) for any $i \in N$, there is $i \in B_i$, and $j \in N$ makes $B_j = N$; (2) for any $i \in N$ and $K \in \hat{C}^L(B_i \setminus \{i\})$, there exists $j \in N$ such that $K = B_j$ for any $\{i,j\} \in L$. Then, the set of all admissible n-tuples $B=\{B_1,B_2,\cdots,B_n\}$ on the graph (N,L) can be denoted by B^L.

Definition1 For classical graph games (N,v,L), n-dimensional average tree solution $AT(N,v,L)$ is defined as

$$AT_i(N,v,L) = \frac{1}{|B^L|}\left(\sum_{B \in B^L}\left(v(B_i) - \sum_{K \in \hat{C}^L(B_i \setminus \{i\})} v(K)\right)\right), i=1,2,\cdots,n \tag{1}$$

Where $|B^L|$ is the number of elements in B^L.

3.2 Modified weight calculation based on TOPSIS improved cloud gravity method

This paper uses the Cloud TOPSIS model to calculate the weight of each enterprise. Firstly, an m-dimensional comprehensive cloud is constructed, and then the queuing theory method is used to determine the weight of each evaluation index, and then TOPSIS method is used to calculate the relative closeness of each shipping enterprise to the ideal solution, so as to express the bearing of influencing factors and obtain the revised profit value. The specific calculation steps are as follows.

(1) Build a cloud model of evaluation indicators.

Invite n experts to score the above m influencing factors respectively., and the obtained value is recorded as $E_{x_1} \sim E_{x_n}$. According to the formula (2) and formula (3), the expected value E_x and entropy E_n of the scoring cloud model are obtained as follows.

$$E_x = \frac{E_{x_1} + E_{x_2} + \cdots + E_{x_n}}{n} \tag{2}$$

$$\frac{\max(E_{x_1}, E_{x_2}, \cdots, E_{x_n}) - \min(E_{x_1}, E_{x_2}, \cdots, E_{x_n})}{6} \tag{3}$$

(2) Construction of m-dimensional integrated cloud. The gravity of the comprehensive cloud can describe the state of the system. The gravity of the m-dimensional comprehensive cloud can be represented by a vector $T = (T_1, T_2, \cdots, T_m)$, where $T_k = (E_x)_m \times w_m, k = 1, 2, \cdots, m$, E_x is the expected value of the kth influencing factor, and w_k is the weight value of the kth influencing factor.

(3) Determine the weight of each index based on queuing theory.

According to formula (4), the weight w_k of the influencing factor of item k is calculated.

$$w_k = \frac{1}{2} + \frac{\sqrt{-2\ln\left(\frac{2(k-1)}{m}\right)}}{6}, 1 < k \le \frac{m+1}{2}; w_k = \frac{1}{2} - \frac{\sqrt{-2\ln\left(2 - \frac{2(k-1)}{m}\right)}}{6}, \frac{m+1}{2} < k \le m \tag{4}$$

m is the number of influencing factors, and w_k will be normalized according to formula (5).

$$w_k^* = \frac{w_k}{\sum_{k=1}^{m} w_k}, k = 1, 2, \ldots, m \tag{5}$$

(4) Calculate the distance between the cloud center of gravity and the ideal solution based on TOPSIS method. According to the TOPSIS idea, the positive and negative ideal states of the system are expressed as (+)(-), respectively. Then the cloud gravity vector in the ideal state is $T^{+(-)} = E_x \times w_k = (T_1^{+(-)}, T_2^{+(-)}, \cdots, T_m^{+(-)})$. According to formula (6) and formula (7) , the Euclidean distance D_i^+, D_i^- of the ith enterprise are

$$D_i^+ = \sqrt{\sum_{k=1}^{m} (T_k - T_k^+)^2}, i = 1, 2, \ldots, n \tag{6}$$

$$D_i^- = \sqrt{\sum_{k=1}^{m} (T_k - T_k^-)^2}, i = 1, 2, \ldots, n \tag{7}$$

(5) The correction coefficient is used to measure the change of cloud center of gravity.

Calculate the relative progress α_i according to formula (8).

$$\alpha_i = \frac{D_i^-}{D_i^+ + D_i^-}, i = 1, 2, \ldots, n \tag{8}$$

According to formula (9), α_i is normalized to obtain β_i as the weight of each enterprise.

$$\beta_i = \frac{\alpha_i}{\sum_{i=1}^{n} \alpha_i}, 0 \le \beta_i \le 1 \quad (9)$$

According to formula (10), the correction coefficient $\Delta\lambda_i$ of each enterprise is calculated in turn, where n is the number of indicators.

$$\Delta\lambda_i = \beta_i - \frac{1}{n} \quad (10)$$

3.3 Improved Cloud TOPSIS-AT solution model

In this paper, the initial profit distribution scheme of shipping alliance is obtained according to the traditional AT solution model, and then Cloud TOPSIS method is used to calculate the correction weight to adjust the scheme. Finally, the Cloud TOPSIS-AT solution profit distribution model considering the limitation of communication structure and the correction of profit influencing factors in shipping alliance is obtained. The formula of the model is as follows.

$$AV_{\mathrm{i}}(N,v,L) = AT_{\mathrm{i}}(N,v,L) + \Delta\lambda_i * V(S) = \frac{1}{|B^L|}\left(\sum_{B \in B^L}\left(v(B_i) - \sum_{K \in \hat{C}^L(B_i \setminus \{i\})} v(K)\right)\right) + \left(\beta_i - \frac{1}{n}\right) * V(S) \quad (11)$$

Among them, $V(S)$ is the total profit of the alliance.

4. Example analysis

This paper selects the shipping alliance composed of freight enterprises, shipping enterprises and port operators as the research object. We mark each enterprise as Enterprise 1, 2 and 3. And set the communication structure limitation between Enterprise 1 and 3, so that Enterprise 2 occupies a key position in the alliance, that is, $N = \{1,2,3\}$, $L = \{\{1,2\},\{2,3\},\{1,2,3\}\}$. It is assumed that the profits that Enterprises 1, 2 and 3 can obtain by operating independently are $V(1)=13, V(2)=15$ and $V(3)=18$ respectively. In the shipping alliance, we predict $V(\{1,2\})=36, V(\{2,3\})=45$, $V(\{1,3\})=45, V(\{1,2,3\})=65$ without considering the limitation of the communication structure.

4.1 Profit distribution scheme of traditional AT solution model

When only considering the influence of inter-alliance communication structure constraints, according to formula (1), the initial profit distribution scheme of shipping alliance based on traditional AT solution model can be obtained $AT_1(N,v,L)=15.34$ .Similarly, $AT_2(N,v,L)=28, AT_3(N,v,L)=21.67$ .In addition, other scholars mostly use Shapley value method in the study of profit distribution. Because this method is relatively mature, this paper does not discuss in detail. According to the Shapley value method, the profit distribution scheme of shipping alliance is 19 for Enterprise 1, 20 for Enterprise 2 and 26 for Enterprise 3.

Table 1. Enterprise 1 Profit influencing factors and positive and negative ideal state scores.

Factor	1	2	3	4	5	6	7	8	9
Expert 1	0.75	0.72	0.81	0.78	0.85	0.78	0.88	0.90	0.82
Expert 2	0.89	0.78	0.85	0.70	0.72	0.85	0.88	0.85	0.78
Expert 3	0.66	0.89	0.73	0.82	0.90	0.70	0.78	0.88	0.88
Expert 4	0.88	0.88	0.76	0.76	0.78	0.72	0.94	0.83	0.71
Expert 5	0.78	0.70	0.74	0.87	0.80	0.87	0.90	0.94	0.80
Positive	0.89	0.89	0.85	0.87	0.90	0.87	0.94	0.94	0.88
Negative	0.66	0.70	0.73	0.70	0.72	0.70	0.78	0.83	0.71
Factor	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Expert 1	0.70	0.60	0.82	0.75	0.68	0.92	0.88	0.89	0.88
Expert 2	0.60	0.75	0.90	0.68	0.75	0.94	0.89	0.82	0.92
Expert 3	0.78	0.60	0.85	0.71	0.72	0.88	0.95	0.89	0.85
Expert 4	0.62	0.63	0.82	0.72	0.67	0.90	0.93	0.84	0.80
Expert 5	0.81	0.68	0.88	0.78	0.65	0.95	0.97	0.94	0.89
Positive	0.81	0.75	0.90	0.78	0.75	0.95	0.97	0.94	0.92
Negative	0.60	0.60	0.82	0.68	0.65	0.88	0.88	0.82	0.80

Table 2. Expected value, entropy and weight value of each influencing factor of Enterprise 1.

Factor	1	2	3	4	5	6	7	8	9
E_x	0.79	0.79	0.78	0.79	0.81	0.78	0.88	0.88	0.80
E_n	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03
w_k	1.00	0.85	0.79	0.75	0.71	0.68	0.65	0.62	0.58
w_k^*	0.11	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.06
Factor	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
E_x	0.70	0.65	0.85	0.73	0.69	0.92	0.92	0.88	0.87
E_n	0.04	0.03	0.01	0.02	0.02	0.01	0.02	0.02	0.02
w_k	0.50	0.42	0.38	0.35	0.32	0.29	0.25	0.21	0.15
w_k^*	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02

4.2 Profit distribution scheme of improved cloud TOPSIS-AT model

In order to fully consider the commitment of each profit influencing factor, 18 profit influencing factors were selected. Five experts in the shipping field are invited to use the five-level scale method to score the 18 influencing factors of each shipping enterprise in the alliance in the range of (0,1), and determine the positive and negative ideal state, as shown in Table 1.

According to formula (2) to (5), the expected value, entropy and weight of each influencing factor of Enterprise 1 can be calculated, as shown in Table 2.

According to the above data, it can be obtained that the comprehensive cloud center of gravity of Enterprise 1 is $T = \begin{pmatrix} 0.08, 0.07, 0.06, 0.06, 0.06, 0.06, 0.06, 0.06, 0.05, \\ 0.04, 0.03, 0.03, 0.03, 0.02, 0.03, 0.02, 0.02, 0.01 \end{pmatrix}$, and the comprehensive cloud center of gravity of positive and negative ideal state is

$$T^{+}=\begin{pmatrix}0.09,0.08,0.07,0.07,0.07,0.06,0.06,0.06,0.05,\\0.04,0.03,0.04,0.03,0.03,0.03,0.03,0.02,0.01\end{pmatrix},T^{-}=\begin{pmatrix}0.07,0.06,0.06,0.06,0.05,0.05,0.05,0.05,0.04,\\0.03,0.03,0.03,0.03,0.02,0.03,0.02,0.02,0.01\end{pmatrix}$$

respectively. According to formula (6) to (10), the Euclidean distance, relative closeness, enterprise weight and correction coefficient of Enterprise 1 can be obtained. Similarly, the variable data of Enterprises 2 and 3 are shown in Table 3.

Table 3. Euclidean distance, relative closeness, enterprise weight, correction coefficient value.

	Enterprise 1	Enterprise 2	Enterprise 3
D_i^+	0.0217	0.0173	0.0098
D_i^-	0.0232	0.0235	0.0078
α_i	0.5167	0.5761	0.4430
β_i	0.3364	0.3751	0.2884
$\Delta\lambda_i$	0.0031	0.0418	-0.0449

According to formula (11), the final profit allocation quotas of each enterprise in the shipping alliance can be calculated as $AT_1=15.39, AT_2=29.17, AT_3=20.70$ respectively.

4.3 Results analysis

Table 4. Example alliance independent operation, Shapley value method, traditional AT solution model, Cloud TOPSIS-AT solution model profit distribution scheme.

	Enterprise 1	Enterprise 2	Enterprise 3
Independent operation	13.00	15.00	18.00
Shapley value method	19.00	20.00	26.00
Traditional AT solution model	15.34	28.00	21.67
Cloud TOPSIS-AT solution model	15.34	28.00	21.67

Through the comparative analysis of the calculation results of different profit distribution schemes in Table 4, it can be found that in view of the limitation of the communication structure of the shipping alliance, the higher position of Enterprise 2 should obtain more profit distribution. Compared with the Shapley value method, the profit distribution scheme using the traditional AT solution model is more reasonable and practical significance. Due to the introduction of the correction coefficient of the influencing factors, the modified profits of Enterprises 1 and 2 exceed the profit distribution scheme of the traditional AT solution model, while the modified profits of Enterprise 3 are lower than the profit distribution scheme of the traditional AT solution model. Through the observation of case data, the results obtained are in line with the case. The above results verify the effectiveness and feasibility of the Cloud TOPSIS-AT solution model proposed in this study in solving the profit distribution problem of shipping alliance.

5 Conclusion

Aiming at the limitation of communication structure and other factors affecting the profit distribution of enterprises in the shipping alliance, this paper introduces the Cloud TOPSIS method to improve the profit distribution scheme of the shipping alliance based on the traditional AT solution model, constructs the modified weight calculation model, proposes the

Cloud TOPSIS-AT solution model, and obtains the final profit distribution scheme of the shipping alliance. Through empirical analysis, compared with the Shapley value method and the traditional AT solution model, it is found that Cloud TOPSIS-AT solution model takes into account the constraints of the communication structure and the differences in the factors of the alliance members in the cooperation, and obtains a more reasonable profit distribution plan. The actual scope of the application is more extensive. This study has guiding significance in the field of profit distribution of shipping alliance, which can provide a reference for the stable operation of practical and effective shipping alliance and promote the healthy development of shipping market economy. However, this paper assumes that the profit is an exact value, and future research can consider the profit distribution problem when the expected profit of the alliance is a fuzzy number.

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