Benefit Distribution of Yunnan's Cross-Border Logistics Alliance Based on Improved Shapley Model

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Abstract: Under the "One Belt and One Road" initiative, Yunnan's cross-border logistics will usher in great changes and development. The development of cross-border logistics alliances in Yunnan has become an inevitable requirement, instead of the existing loose model that only cooperates with each other in logistics links and settles separately. The Shapley model of alliance benefit distribution only distributes benefits from the perspective of completing profits individually and completing profits through cooperation. The improved model proposed in this article fully considers the differences in logistics infrastructure and logistics operation levels between domestic and foreign logistics companies, introducing three correction coefficients of cost expenditure, risk bearing and LPI(Logistics Performance Index), and taking into account the contribution and fairness of the members of the alliance.

1. Introduction

As one of the important nodes of the "One Belt and One Road" initiative, Yunnan is positioned as a radiating center for South Asia and Southeast Asia. Yunnan is also a major international channel connecting China to South Asia and Southeast Asia. Yunnan's cross-border logistics development will usher in a golden period. Because cross-border logistics spans different countries, especially Southeast Asian countries where the logistics infrastructure is still very weak and the level of logistics operations is still relatively low, it is inevitable to form a cross-border logistics alliance with large Yunnan's logistics companies as the core enterprises [1]. The Logistics Performance Index (LPI) issued by the World Bank has become a tool to evaluate the comprehensive level of cross-border logistics performance in various countries. The six sub-elements of the LPI index include customs efficiency, infrastructure level, international transportation capabilities, logistics quality and service capabilities, cargo traceability and the ability to track international cargo transportation and the timeliness of cargo transportation. China's LPI comprehensive score is higher than that of Southeast Asian and South Asian countries adjacent to Yunnan [2].

The distribution of benefits within the cross-border logistics alliance affects the operation of the alliance, and it is particularly important to build a reasonable benefit distribution mechanism that reflects contributions and fairness [3].

The current literature on the benefit distribution of cross-border logistics alliances is still relatively rare [4]. The Shapley model is used in the study of the benefit distribution of logistics alliances, based on the assumption that each member of the alliance can complete tasks and make profits individually [5]. The improved model proposed in this paper fully takes into account the differences in logistics infrastructure, logistics operation level and LPI index of domestic and foreign logistics companies and introduces three correction coefficients such as cost expenditure, risk bearing and LPI comprehensive score.

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2. Revised Shapley Model

2.1. Traditional Shapley model [6]

The benefit distribution problem of the cross-border logistics alliance is actually a multi-player cooperative game, and the Shapley model is used to solve such problems. It can determine the distribution of this maximum benefit when n subjects obtain the maximum benefit through cooperation.

Assuming that a logistics alliance set I is composed of n different member companies i and this set is expressed as $I = \{1,2,...,n\}$. When each member in the alliance works independently, the income is $V(i)$; when the members of the alliance obtain a certain total income $\Phi(v)$ through cooperation, the alliance needs to transfer the income to each player in the game. The Shapley value $\varphi_i(v)$ is the profit distribution value of enterprise i.

For the Shapley model to be established, the following conditions need to be met as formula (1),(2),(3):

$$\sum_{i=1}^{n} \varphi_i(v) = \Phi(v) \tag{1}$$

$$\Phi(v) \geq \sum V(i), i = 1,2,\dots,n \tag{2}$$

$$\varphi_i(v) \geq V(i) \tag{3}$$

Formula (1) means that the total income of the alliance must be equal to the sum of the total income of individual members of the alliance; Formula (2) means that the total income of the alliance is greater than the simple sum of the income of each member alone; Formula (3) means that the share benefit of member i in the alliance is higher than the benefit when the member i works alone.

The above conditions are met, the relevant calculation of the Shapley value can be carried out. In the set I , S_i represents all the subsets of subject i, the number of elements of the subset is $|S|$, the weighting factor is $\omega(|S|)$, the income of the subset S of subject i is $V(S)$, and the benefit is $V(S/i)$ after removing member i from set S. Therefore, the benefit of a single member can be expressed as formula (4), and the weighting factor $\omega(|S|)$ can be expressed as formula (5):

$$\varphi_i(v) = \sum_{S \subseteq Si} \omega(|S|)[V(S) - V(S/i)] \tag{4}$$

$$\omega(|S|) = \frac{(|S|-1)!(n-|S|)!}{n!} \tag{5}$$

2.2. Revised Model

Modification of the model is based on the following assumptions:

- The necessity of cross-border logistics alliance. Cross-border logistics alliances are different from domestic logistics alliances. In order to relay cross-border logistics tasks, domestic and foreign logistics companies can only complete and profit from alliances. Alliances can obtain more benefits and competitive advantages on the basis of integrating superior resources.
- The simulation of the data. The Shapley model is applied to the distribution of alliance benefits and requires more accurate data. At present, the cost and profit of logistics operations are relatively transparent and predictable. However, due to the particularity of the cross-border logistics business, domestic and foreign logistics companies cannot complete the cross-border logistics business alone, and we cannot truly measure the profits achieved by the companies in the alliance alone. So, we use simulation calculations to determine the profitability of domestic and foreign logistics companies alone.

The operating costs and available profits of domestic logistics companies overseas are based on the overseas branches of domestic logistics companies. The operating benefits and costs of domestic and foreign segments are added to simulate the benefits and costs paid by independent operations. The operating costs and available profits of overseas logistics companies in the domestic part are determined by referring to the proportion of logistics costs to GDP. Different countries have different logistics costs and GDP ratios and need to be considered separately. The operating benefits and costs of domestic and foreign sectors are added to simulate the benefits and costs paid by separate

operations.

- Fairness among alliance members. As domestic and foreign logistics companies have large differences in business level, cost expenditure, profitability, risk-taking and logistics performance, the distribution of benefits of cross-border logistics alliances needs to reflect fairness. We think that the factors that affect the fairness of members' distribution are cost, risk and LPI index. Generally speaking, the core members of the alliance bear risk costs and responsibilities that exceed those of other members during the entire operation process. In order to consider the principle of fairness, the cost spent by the members of the alliance, the risk assumed and the LPI comprehensive score are introduced as the correction coefficient.

The correction factors are as follows:

- Cost coefficient(*Hv*). For the cross-border logistics business that must be completed by the members of the alliance, if the profit distribution of the members in the alliance is only considered from the profitability of separately undertaking the logistics business, the difference between domestic and foreign logistics operation conditions is ignored, and the party who has invested more in the cost will feel unfair. Parties with high costs should be compensated with higher benefits. To this end, we introduce a cost coefficient(*Hv*)to modify it.

Suppose hvi is the cost spent by member i in the operation process, after normalization, and the cost coefficient Hvi of member i is obtained. Cost coefficient Hvi can be expressed as formula (6), and normalization can be expressed as formula (7):

$$Hvi = \frac{hvi}{\sum_{i=1}^{n} hvi} \tag{6}$$

$$\sum_{i=1}^{n} Hvi = 1 \tag{7}$$

- Risk coefficient(*Rv*). Due to the influence of factors such as weather and types of goods, logistics companies in different links bear different risks in the implementation of specific logistics tasks. Members with high risk coefficients should receive higher benefit compensation. According to a single cross-border logistics operation, different risk coefficients can be set. In order to reflect the fairness of responsibility and right, we introduce risk coefficients to modify it. The risk coefficient of a single cross-border logistics operation needs to be coordinated and approved by the members of the alliance, and it can also be evaluated by experts in the field of third-party logistics. In general, the risk coefficient Rv_i of each member satisfies the normalization condition as formula (8):

$$\sum_{i=1}^{n} Rvi = 1 \tag{8}$$

- LPI coefficient(*Lv*). In the process of cross-border logistics operations, the performance level and service capabilities of logistics can be comprehensively reflected by LPI scores. In order to reflect the contribution the members, we introduce the LPI coefficient to modify it. Suppose *lvi* is the LPI comprehensive score of member *i*, after normalization, and the LPI coefficient *Lvi* of member *i* is obtained. LPI coefficient *Lvi* can be expressed as formula (9), and normalization can be expressed as formula (10):

$$Lvi = \frac{lvi}{\sum_{i=1}^{n} lvi} \tag{9}$$

$$\sum_{i=1}^{n} Lvi = 1 \tag{10}$$

Considering profitability, cost factors, risk factors and LPI comprehensive scores, according to the opinions of experts in the field and the results approved by the members of the alliance, the weights of all factors affecting the distribution of the alliance's benefits are given as $\chi 1$, $\chi 2$, $\chi 3$, and $\chi 4$ respectively, and the revised Shapley value is obtained as formula (11):

$$\varphi'_i(v) = \chi_1 \varphi_i(v) + \chi_2 \Phi(v)\, Hvi + \chi_3 \Phi(v)\, Rvi + \chi_4 \Phi(v)\, Lvi \tag{11}$$

3. Example

3.1. Initial calculation

Assume that a cross-border logistics project from Kunming to Bangkok needs to pass through China, Laos, and Thailand, the core logistics enterprise A in Yunnan Province is an integrated logistics service that specializes in providing domestic warehousing, transportation and distribution, enterprise B is a logistics enterprise specializing in overseas transportation business in Laos, and Enterprise C is specializing in overseas warehousing business in Thailand. The available information is as follows:

Assuming that the company completes the business alone, company A completes a profit of 500,000 yuan, company B completes a profit of 400,000 yuan, and company C completes a profit of 300,000 yuan. After the integration, company A and company B make a joint profit of 1.5 million yuan, company A and company C make a joint profit of 1.3 million yuan, company B and company C make a joint profit of 1.1 million yuan, and company A, company B and company C make a joint profit of 2.5 million yuan.

According to the Shapley model, the profit distribution of company A is shown in Table 1.

Table 1 Profit distribution of company A (unit: thousand yuan).

	A	A∪B	A∪C	A∪B∪C
V(S)	500	1500	1300	2500
V(S/I)	0	400	300	1100
V(S)- V(S/I)	500	1100	1000	1400
|S|	1	2	2	3
ω(|S|)	1/3	1/6	1/6	1/3
ω(|S|)[V(S)- V(S/I)]	500/3	1100/6	1000/6	1400/3

According to formula (4), the distributable profit of enterprise A is 5900/6 thousand yuan.

In the same way, the distributable profits of enterprises in the alliance obtained by the Shapley model are shown in Table 2.

Table 2 Distributable Profits of Enterprises A, B and C (Unit: Thousand Yuan).

	A	B	C
Φ (ν)	5900/6	2500/3	4100/6

Obviously

ΦA(ν)>500,000, ΦB(ν)>400,000, ΦC(ν)>300,000;

ΦA(ν)+ ΦB(ν)>1500,000;

ΦB(ν)+ ΦC(ν)>1100,000;

ΦA(ν)+ ΦC(ν)>1300,000;

ΦA(ν)+ ΦB(ν) + ΦC(ν)=2500,000

It can be seen that this plan satisfies individual rationality and collective rationality and every enterprise is willing to participate.

3.2. Correction calculation

In 2018, the LPI scores of China, Laos and Thailand were 3.61, 2.7 and 3.41 respectively. Next, make the following corrections to the initial results.

According to the opinions of experts in the field and the negotiation of enterprises in the alliance, the normalized cost and risk correction coefficients can be given. Correction coefficients are shown in Table 3.

Table 3 Normalized correction coefficients.

	Hv	*Rv*	*Lv*
A	0.35	0.4	0.37
B	0.35	0.3	0.28
C	0.3	0.3	0.35

According to the opinions of experts in the field and the results of negotiations between enterprises

in the alliance, the profitability, cost expenditure, risk bearing and LPI logistics performance are assigned weights of 0.3, 0.3, 0.2 and 0.2 respectively.

The final profit distribution of companies A, B, and C can be obtained respectively (unit: thousand yuan).

$\Phi'A(v)= 0.3\times5900/6+2500\times0.3\times0.35+2500\times0.2\times0.4+2500\times0.2\times0.37=942.5$

$\Phi'B(v)= 0.3\times2500/3+2500\times0.3\times0.35+2500\times0.2\times0.3+2500\times0.2\times0.28=802.5$

$\Phi'C(v)= 0.3\times4100/6+2500\times0.3\times0.3+2500\times0.2\times0.3+2500\times0.2\times0.35=755$

3.3. Result analysis

Through the amendment, the distributed benefits of enterprises A, B and C in the alliance have changed. Among them, the final distributed profits of A and B have decreased, while the final distributed profits of C has increased. See Table 4 for details.

Table 4 Comparison table of benefit distribution (Unit: Thousand Yuan).

	Φ(v)	Φ' (v)
A	983.3(5900/6)	942.5
B	833.3(2500/3)	802.5
C	683.4(4100/6)	755

If an enterprise has a high level of logistics business, it has strong profitability and low cost. As a core enterprise, company A has a higher level of logistics business than logistics companies B and C, but it has assumed greater liability risks. From the perspective of profitability, cost expenditure, risk bearing and LPI, the weight of profitability and cost expenditure are equal, while the weight of risk bearing and LPI performance is smaller. Because the core enterprise cannot complete the task alone, taking into account the above four factors and setting the weight reasonably can reflect the fairness between the alliance members. After the amendment, the income of enterprises A and B has decreased respectively, but it is still higher than the income of completing the task alone; the income of enterprise C has increased, and it reflects its' corresponding alliance contribution and relative fairness.

4. Conclusion

The revised Shapley model fully considers fairness and contribution factors when there are gaps in various indicators of domestic and foreign logistics. At the same time, it also plays a role in controlling the costs and risks of the members of the alliance.

With the continuous advancement of the "one Belt and one Road" and the continued strengthening of cooperation between China and Southeast Asian countries, the gap in logistics infrastructure, logistics operation level, logistics cost expenditure, logistics operation risk gap and LPI ranking between domestic and foreign countries will surely be further narrowed. The indicators of the members converge.

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