Research on the Rural Express Alliance based on ANP improved profit Allocation

Yufeng Zhuang, Bin Zhang

Beijing University of Posts and Telecommunications, Beijing 100876, China

*Corresponding author e-mail: zhuangyf@bupt.edu.cn 1, zhangbin1992916@163.com 2

Abstract. Online shopping platform in rural distribution difficulties, leading to rural online shopping market and logistics market development is slow. At present, China Post and other private courier companies are not possible to do. So we need to build distribution alliances. Reasonable profit allocation mechanism is the key to the stable development of this distribution alliance. So we proposed the Shapley Value Method and the ANP Improved Model to allocate profits. Finally, the rationality of the method is proved by numerical analysis before and after using the corrected Shapley Value.

1. Introduction

In the era of rapid development of the Internet, because online shopping is fast, easy, cheap makes e-commerce has gradually become the main way of consumption. But the reasons for rural geographical factors, resulting in high rural distribution costs, making e-commerce in rural areas slow. In the end of distribution, China Post has long been rooted in the vast rural areas, distribution network perfect, but the end of the high cost of distribution, timeliness is poor. Private Courier business due to cost investment and profit problems, only distributed to the township. Rural logistics in the "last 1 km" in the realization of circulation and service consumers is very important [1]. Rural terminal distribution is not only an important part of rural logistics, but also open up the rural market, the biggest bottleneck.

Combined with the actual situation of rural areas, the current analysis of the existing distribution model, we found that relying solely on postal or Shun Feng and a private express to enhance the development of rural logistics is very difficult. So the proposed third-party logistics alliance, the integration of the advantages of each courier to reduce distribution costs and reduce the difficulty of distribution, open up rural online shopping market. Logistics distribution alliance in the distribution of profits is also affecting the logistics and distribution can be efficient and sustained key factors. Many scholars have studied the different methods of distribution in different areas. Karl Morasch studied profit sharing in a production joint venture based on the Stackelberg cooperative game model [2]. Gong Jun tao puts forward the application of ANP in supplier selection [3]. Gavirneni analyzed how to determine the proportion of each partner in the n-man cooperation game configuration [4]. Dai Jianhua puts forward a correction algorithm based on risk factor based on Shapley's dynamic alliance enterprise benefit distribution [5].

However, there are few studies to solve the problem of profit distribution of rural logistics and distribution alliance. Therefore, this paper studies the profit distribution of logistics alliance based on the classical Shapley value method. In addition, we also consider the important factors that affect the
distribution of logistics in the actual distribution operation, and propose an improved model combined with AHP method. Taking into account the AHP itself has some limitations, proposed ANP modified improved shapley model. Finally, the results of the classical Shapley, ANP modified improved numerical studies are compared, thus demonstrating the improved model rationality and practicability.

2. The Shapley Model

2.1. Shapley value method model

The Shapley method is a mathematical method proposed by Shapley L.S. to solve the problem of Cooperative n-person game. When an individual engaged in an economic activity, for each of them a combination of each form of cooperation, will be some benefits, when the interests of people between the activities of non-confrontational, the increase in the number of cooperation will not cause the reduction of efficiency, so that the cooperation of all n individuals will bring the greatest benefits, Shapley value method is to allocate the maximum benefit of a program.

We define the Shapley model as following:

Assumed that a set of n carriers is \( N = \{1, 2, \ldots, n\} \), and \( S \subseteq N \) is any subset in \( N \), which represents one alliance that the carrier may be formed. \( v(S) \) is a characteristic function to represent the maximum payoff that the alliance \( S \) achieve. Let \( \phi_i(v) \) be the allocated profit gained by member \( i \) in the n-person cooperative game, and \( \phi(v) \), the Shapley value, should be expressed as:

\[
\phi_i(v) = \sum_{i \in S} \omega(|S|)[v(S) - v(S \setminus i)]
\]

(1)

\[
\omega(|S|) = \frac{(n - |S|)!(|S| - 1)!}{n!}
\]

(2)

where \( v(S \setminus i) \) is the payoff removed carrier \( i \) from set \( S \), and thus \( [v(S) - v(S \setminus i)] \) represents the marginal contribution that carrier \( i \) bring to \( S \). \(|S|\) is the element number in the subset, \( \omega(|S|) \) is weighted factor that can be regarded as the probability of each alliance \( S \) happens. That is to say, from a probabilistic viewpoint, the Shapley value is exactly the marginal contribution expectation of the carrier \( i \).

2.2. Limitations of the basic model

Limitation: In the above problem, the Shapley method is used to solve the problem of the distribution of benefits, and the cost of the personalized service is assumed by the partner enterprise in the distribution process. That is to say, the service cost of the partner enterprise is equal, that is, for the economic activity set \( I = \{1,2, \ldots, n\} \), each partner to bear the cost of individual factors are \( 1/n \), that is, each member companies bear \( 1/n \) times the cost of individuality. There are some shortcomings in the Shapley value, which assumes that members of the coalition are on an equal footing and do not take into account the individualized service costs incurred by partner companies in the distribution process. However, ignoring the impact of other factors on the distribution of profits in the league. Obviously, this is an idealized situation, in the real economic activities is almost impossible.

Hence, in the next chapter, we will introduce an improved Shapley value method, which will take those influent factors into account, so as to let the profit distribution more fair and reasonable in the rural express alliance.
3. Improved the Shapley Model

3.1. AHP
In the mid-1970s by the US operations scientist Thomas Seti (T.L. Satty) formally put forward. Analytic Hierarchy Process(AHP) to analyze the influencing factors of influencing the actual logistics distribution, analyze and evaluate the proportion of each factor, redefine the league's profit distribution weight, and correct the shapely model to rationalize the distribution.

Using AHP Method to Establish Alliance Hierarchical Structure Model. According to expert advice, market research and literature collection, we summarize the main factors affecting the distribution of logistics alliance. Finally, we have a comprehensive evaluation of the index system. As shown in Fig.1, the target layer of the system is getting a comprehensive assessment of the courier, and the rule layer includes three of the most important factors that cannot be ignored in the distribution, namely, cost input, logistics service, and enterprise competitiveness. Each specific courier is an alternative and needs to be evaluated in this system.

![Figure 1. Comprehensive Evaluation System of Courier firm](image)

3.2. ANP
Analytic Network Process(ANP) is an improvement in AHP. The AHP method divides the system into hierarchies, taking into account only the domination and influence of the next level elements on the next level of elements, and assuming that the elements at the same level are independent of each other and that there is no interdependent relationship. Many complex systems must consider the internal elements of the hierarchy and the underlying elements of the upper element of the feedback effect, the relationship between the elements of the system with a similar network structure Rather than a simple hierarchical structure, ANP theory more accurately describe the relationship between objective things, is a more effective and practical decision-making methods. Here are not detailed ANP specific algorithm formula reasoning, the details of reference [6].

In the actual logistics alliance system, the cost of investment is bound to affect the logistics service is good or bad, thus affecting the competitiveness of enterprises, on the contrary, the strength of the competitiveness of enterprises and the level of cost inputs, logistics services are inseparable. The ANP method is used to revise the comprehensive evaluation system of the alliance, and the interaction between the elements of the same layer and the elements of the lower layer is considered. As the ANP method is computationally intensive, it is necessary to use software. Here is the use of Rozann W. Satty and William Adams in the United States launched a super decision (Super decision, here in after referred to as SD) software, the software based on ANP theory, has successfully compiled ANP, ANP is a powerful computing tool.

As shown in Fig.2, Super Decision generated ANP revised courier evaluation system.
AHP and ANP can be used to evaluate indicator weights. Weight analysis is performed by layer of judgment matrix. Since the ANP model is more accurate than the AHP. So this article only considers ANP corrections Shapley. After we calculate the weight we have to fix it further and verify the usability. This article has passed the expert investigation method and the actual research, the data collection establishes the influence relation among each factor. After calculating the weighting factor by ANP, the algorithm of compensation factor for compensation is introduced.

Assumed that the determined evaluation indicator by ANP method is \( W_i \) \((i = 1, 2, \ldots, n)\). Obviously, \( W_i \) satisfies the condition \( \sum W_i = 1 \). For currier \( i \), let \( \Delta W_i \) be the correction factor of profit allocation in campus express alliance. Since the shapely model is judged by the contribution of the coalition members to the marginal contribution of the alliance, it is assumed that the position of the coalition is equal, meaning that these factors are not considered for the model correction, and that is the same as \( 1/n \). So use the ANP correction to get the \( W_i \) by calculating the compensation factor as follows:

\[
\Delta W_i = W_i - 1/n
\]  

where \( 1/n \) represents the average level in the distribution. When the courier's evaluation index \( W_i \) is higher than the average standard, \( \Delta W_i > 0 \), which means the currier should be compensated in the allocation; Conversely, when \( W_i \) is below the average, \( \Delta W_i < 0 \), the currier will get punishment.

Supposed that \( V(I) \) is the total revenue in the campus express alliance, then the improved Shapley value \( \varphi'(v) \) can be expressed as:

\[
\varphi'(v) = \varphi(v) + V(I) \times \Delta W_i
\]  

Because
\[ \sum [V(I) \times W_i] = V(I) \times \sum (W_i - 1/n) \]
\[= V(I) \times (\sum W_i - \sum 1/n) \]
\[= V(I) \times 0 \]
\[= 0 \]

Therefore
\[\sum \phi_i^*(v) = \sum [\phi_i^*(v) + V(I) \times \Delta W_i] \]
\[= \sum \phi_i^*(v) + \sum [V(I) \times \Delta W_i] \]
\[= V(I) + 0 \]
\[= V(I) \]

It is reasonable to prove that the sum of the adjusted profits is unchanged.

4. Case Analysis

4.1. Case description

Now suppose the members of the Union are China Post A, Shun Feng B, rhyme C three courier business, courier business three separate distribution profits \( v(A) = 900,000 \), \( v(B) = 800,000 \), \( v(C) = 500,000 \) set now After the establishment of the Union \( v(A, B) = 2,200,000 \), \( v(A, C) = 2,000,000 \), \( v(B, C) = 1,700,000 \), \( v(A, B, C) = 3,400,000 \).

According to the conditions mentioned above, curriers could achieve more benefits through the cooperation, which is in accordance with the basic conditions of the cooperative game, so we can calculate the initial profit distribution based on Shapley value method.

4.2. Profit allocation based on the Shapley value

Based on the Shapley value method, the calculation process of the profit distribution of currier A in the alliance is as shown in Table 1.

| Table 1. Currier A Obtained Profit Based On Shapley Value. |
|-------------------------|--------|--------|--------|--------|
| \( v(S) \)            | 90     | 220    | 200    | 340    |
| \( v(S \setminus i) \) | 0      | 80     | 50     | 170    |
| \( v(S) - v(S \setminus i) \) | 90 | 140   | 150   | 170    |
| \( |S| \)               | 1      | 2      | 2      | 3      |
| \( \omega(|S|) \)     | 1/3    | 1/6    | 1/6    | 1/3    |
| \( \omega(|v(S) - v(S \setminus i)|) \) | 30 | 70/3   | 25     | 170/3  |

* Unit: 10 Thousand Yuan

By summing the last row values in Table 1, we can get the allocation profit of A:
\[ \varphi_A(v) = 30 + \frac{70}{3} + 25 + \frac{170}{3} = 1,350,000 \text{ yuan} \]

Similarly, \( \varphi_B(v) = 1,150,000 \text{ yuan} \), \( \varphi_C(v) = 900,000 \text{ yuan} \)

Finally, \( \varphi_A(v) + \varphi_B(v) + \varphi_C(v) = 3,400,000 \text{ yuan} \)

Get the results for the Union's largest profit, verify the results reasonable and accurate. As a result of the analysis, the profit distribution of the three companies seems unfair to operators B with high cost inputs and operator B with good service and competitiveness, and the weaker operator C may be divided. So the results are not reasonable, there is room for improvement.

4.3. The improved allocation

We use ANP to calculate the weight of each influencing factor in the total evaluation system. With the super decision we obtain the result of the calculation, we get the final limit weight matrix to obtain the global weight:

| Factor                      | Enterprise scale | Operating cost | 0.192451 |
|-----------------------------|------------------|----------------|----------|
| Number of clients           | 0.125453         | Service quality| 0.092366 |
| Market status               | 0.050028         | Accuracy       | 0.113928 |
| Personnel capital           | 0.128696         | Timeliness     | 0.129654 |
| Storage cost                | 0.072711         | Management costs| 0.049999 |

Table 2. Every Factor Limit Weight Matrix

According to the expert survey method, the literature query and the field research summed up the three distributors of the weight ratio of each factor:

| Factor                      | Cost Input | Logistics Services | Company Competitiveness |
|-----------------------------|------------|--------------------|-------------------------|
| Currier                     | Personnel capital | Storage cost | Operating cost | Management costs | Accuracy | Timeliness | Service quality | Enterprise scale | Number of clients | Market status |
| A                           | 0.41       | 0.41               | 0.41                   | 0.40                | 0.163      | 0.203      | 0.336         | 0.42             | 0.24             | 0.23         |
| B                           | 0.38       | 0.38               | 0.39                   | 0.38                | 0.510      | 0.531      | 0.356         | 0.39             | 0.30             | 0.42         |
| C                           | 0.21       | 0.21               | 0.20                   | 0.22                | 0.327      | 0.266      | 0.327         | 0.29             | 0.46             | 0.35         |

Table 3. Courier Business Each Factor Proportion

Revise the factor according to Table 2 and Table 3:

\( \vec{W} = (0.316, 0.402, 0.281) \)

And thus, the correction factors in the distribution are:

A: \( sW_A = W_A - 1/n = -0.017 \)

B: \( sW_B = W_B - 1/n = 0.069 \)

C: \( sW_C = W_C - 1/n = -0.052 \)

Based on the improved method mentioned before, the revised profit allocation results are as follows:

A: \( \varphi_A'(v) = \varphi_A(v) + V(I) \times sW_A = 129.22 \)

B: \( \varphi_B'(v) = \varphi_B(v) + V(I) \times sW_B = 138.46 \)

C: \( \varphi_C'(v) = \varphi_C(v) + V(I) \times sW_C = 72.32 \)

Compared with the independent operating profit, the postal increase of 392, 200-yuan, SF and rhyme were increased by 584,600 yuan and 223,200 yuan. The new distribution method of Shun Fung
paid higher than the basic Shapley value method, the post was slightly lower than the basic Shapley method, while the rhyme of the decline in profits but still higher than the single income a lot.

5. Conclusion
Analyze the above results that it is pointed out that Shunfeng has a significant proportion in all the influencing factors. although it is defective in the distribution of the "last mile" in the village level, but it has greater advantages in terms of timeliness, accuracy, cost and size of the firm. So in the revised logistics union profit distribution in the larger profits. The post office has played a significant role in the "last mile" of the rural logistics infrastructure in the league, but because of its own market position, distribution efficiency and accuracy rate in the middle of the logistics before the key measure factors are relatively poor, So the total income compared to SF after the amendment to reduce the point. The final YunDa due to their own cost of investment less, low-level business reasons, so the distribution of the remaining two compared to much less. But because of its own low cost and other reasons, resulting in its low cost of delivery, the amount of package compared to the other two more. Therefore, the improved method of Shapley value with ANP correction factor is more scientific and reasonable, so it is more practical and practical in real life.

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