Study of Joint Ventures' Profits Distribution Based on Improved Maximum Entropy Method

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***Abstract*—A good mechanism of profit distribution in supply chain can effectively motivate every member to make efforts to gain profits. Based on the background of joint-venture in project, this paper puts forward a distribution model based on the maximum entropy method, solving the initial distribution with the maximum entropy method, taking full consideration of risk, efficiency,level of efforts,technological innovation and resources which affects the distribution of profits, improving properly with AHP(Analytic Hierarchy Process) method,this model gets the solution of final profit distribution .This idea fully reflects fairness and rationality, and guarantees the stability of the joint venture, which is beneficial to construct of the project and to maximize profit of the all chain.**

***Keywords*-construction supply chain ;profit distribution ; join venture ; maximum entropy method ; AHP**

I. INTRODUCTION

With the deepening reform of China's market economy, the construction market has also ushered in the rapid development, so is the engineering mode which is transforming from traditional DBB mode to general contracting mode. General contracting projects are often of large scale, complex construction, many companies involved in the supply chain nodes, more and more concern is put on how to coordinate the relationship effectively between the members of the engineering supply chain, to build a reasonable, effective and comprehensive mechanism for profit distribution [1]. At present, the academic profit distribution models of supply chain are the Shapely value model [2], the game model [3], income and risk allocation model [4], revenue sharing model [5], and so on.

Due to the late start of construction supply chain, there are not many study of profit distribution model of supply chain. In China, Based on theory and game ideas, Guan Baihai and Hu Pei have researched the consortium income distribution issue of the general contractor consist of the design institute and construction companies and come to the optimal distribution ratio based on optimization design of the total contract revenue between the design institute and construction enterprises [6]; Focused on the enterprise capabilities, considering the effort level and effectiveness coefficient of general contranctors and sub-contractors, Zhang Yun have reached a reasonable ratio to the allocation [7]; From the point of cooperative game, according to the characteristics of project and construction enterprise, Shapley value method was applied to income allocatoin of joint ventures by Yi Xin and Zhang Feilian [8], and so on. But only a few factors have been considered in the study and the complexity of factors affected the profit distribution were not taken full account of. Obviously, rationality and fairness can not be well reflect and each node enterprise of the supply chain also can't be well incented to make the maximum contribution for maximizing the whole revenue of the chain. Therefore, from the quantitative factors affected profit the distribution, this paper argues the revenue allocation of joint ventures in supply of main contracting project, to guide the profit distribution between the joint venture company.

II. DESCRIPTOING OF THE PROBLEM

This thesis discusses the main contracting project mode of joint ventures, so it is given in the definition of the main contracting project of joint venture: main contracting project of joint venture is that complementary enterprise integrates advantageous resources to form a greater competitive advantageous union to bid to obtain a general contracting projects as a bidder, But every member of joint ventures shall sign the joint bid agreement to expressly appoint one's jobs, responsibility, the implementation of project should be responsible for owners. Apparently, the joint venture is an one-time temporary organization driving by market opportunities. Under the assumption that enterprises maximize individual interests, the interests relationship is the core. if the revenue allocation is not reasonable, some members will reduce the enthusiasm in the cooperation of supply chain, and weakening the willingness and ability of the follow-up cooperation, which will probably lead to the reduce of efficiency and stability of the supply chain, or even eventually led to dissolution or collapse. Therefor, building a reasonable revenue allocation mechanism is the key to motivating the associate enterprises in joint venture to make efforts to gain interest for joint ventures, maintain the stablity and improve the effiectiveness of the whole project.

As every member of the joint venture has different concept of fairness and reasonablity, it is unreasonable to distribute the profit merely considering the investiment, many factors such as the member's effort level, efficiency coefficient, technical innovation, and their ownrisk, impacked the ventures' revenue. So considering all these factors to form a revenue mechanism will well refect the fairness and reasonablity. In the thesis, the upfront fee will be ignored to solve the contradiction caused by the venture's

unreasonable allocation as possible. Which lead the reduce of the whole profit of the general contracting project. In this way, the enterprise of the venture make efforts together and align with the direction to maxmize the profit, thus not only improving the duration, cost, quality of the project and revenue allocation of every member, but also improving the efficiency which is beneficial to social economy.

III. THE PROFIT DISTRIBUTION MODEL OF TRADITIONAL MAXIMUM ENTROPY METHOD

The maximum entropy principle, when we need to predict the probability distribution of a random event, our prediction should meet the conditions of all known and unknown and do not do any subjective assumptions. In this case, the probability distribution of the most uniform, predictable minimum risk. Because then the probability distribution of the maximal entropy, so people call this model the maximum entropy model. The formula for the definition of entropy as following:

$$H_{(x)} = -\sum_{i=1}^{n} p(i)\ln p(i) \qquad (1)$$

$$H_{(x)} = -\int_R f(x)\ln f(x)d(x) \qquad (2)$$

The above formula (1) is the definition of a discrete random variable entropy ; formula (2) is the definition of the entropy of the continuous random variables. $p(i)$ represents the probability of information $x(i)$ appearance. $f(x)$ is the function for the probability of continuous random variables, and $H(x)$ characterizes the amount of information and is a measure of a system state uncertainty.

In 1957, Jaynes proposed guidelines of the probability distribution of statistical inference in reasoning based on partial information. You must select the largest entropy's probability distribution [9]. The subjective component of the probability distribution contains a minimum, thus the result is the most objective [10], which is the principle of maximum entropy method.

A. *Maximum entropy method in the supply chain*

References [11, 12, 13] using logical reasoning methods can prove a business cooperation exists only the distribution of benefits, and the distribution of the benefits of the supply chain can be seen as a reasonable solution to meet certain conditions of maximum point. So you can use the maximum entropy principle to establish the distribution of benefits of supply chain model, that is, without considering other factors in the interests of the crude allocated in the objective case.

Assuming the supply chain enterprises constitute a supply chain enterprises industry collections I ,Some subset of I called Alliance S ($S \in I$), i ($i = 1 \cdots n$) represents one member in the Alliance, $v_i(I)$ stands for the interests of the enterprises i participate in the Alliance I after the overall best interests of the whole $V(I)$, $\varphi(i)$ stands for the interests that enterprises i do not participate in any alliance alone but do it itself alone.

Distribution of benefits due to supply chain enterprises must follow the win-win principle. The distribution of benefits of the supply chain can not be part of members interests while another part of the members did not gain, and interests of the members involved in the supply chain from the supply chain must be higher than the benefits obtained separately not involved in the supply chain [10], so

$$v_i > \varphi(i)$$

$$\sum_{i=1}^{S} v_i > \varphi(S)$$

Not consider subjective factors assigned based on the theory of cooperation, the allocation model based on the interests of the maximum entropy method is:

$$MaxH = -\sum_{i=1}^{n} p(i)\ln p(i) = -\sum_{i=1}^{n} \frac{v_i}{V(I)} \ln \frac{v_i}{V(I)} \qquad (3)$$

$$s.t\begin{cases} \sum_{i=1}^{N} v_i = V(I) & (4) \\ v_i > \varphi(i) & (5) \\ \sum_{i=1}^{S} v_i > \varphi(S) & (6) \\ V_i > 0 & (7) \end{cases}$$

In the formulas: $p(i) = \frac{v_i}{V(N)}$ ($i = 1, \cdots n$) means the probability of the distribution of benefits that the supply chain gives to the enterprise i .Equation（4）expressed the sum of the interests assigned to each members of the supply chain equals the total interest of the cooperation ; equation（5）expressed the interests assigned to the enterprise involved in the supply chain to be greater than its own separate contract ; equation（6）expressed the sum distributed to each member of Alliance S of I is bigger than the total benefits of Alliance S not in I . Use the Lingo software to work out the model. Finally we can get the result $v(I) = (v_1, v_2 \ldots v_I)$, which is the proposal to divide the benefits.

IV. WEIGHTED IMPROVED DISTRIBUTION OF PROFITS MODEL

Supply chain alliance, it follows the principle of sharing interests. Suppose the supply chain between enterprises resources investment risks are equal, you can absolutely get the fair distribution of benefits. But in reality, the risk coefficient, technological innovation ability are impossible to equal among the members involved in the supply chain. If we still follow the principle of equal allocation, it will be unfair to the invested larger or risk larger enterprise. In this

paper, the multi-factor integrated weighted improvement method is raised based on the maximum entropy method not considering any external factors under the conditions.

A. Quantify and normalize the risk

Actual supply chain enterprises have to bear the many risks, the main taken into account are the environmental risk r_1' 、the market risk r_2' 、technical risk r_3' 、the cooperation risk r_4' , which can be quantified by Fuzzy Comprehensive Evaluation method. According to $r_i = 1-(1-r_1')(1-r_2')(1-r_3')(1-r_4')$ we can get the composite risk which enterprise i should take. Put all the enterprises' composite risk $r = (r_1, r_2 \cdots r_n)$ to the normalization and get $R = (R_1, R_2, \cdots R_n)$.

B. Calculate the coefficient

Similarly, the resource cost of each member in the supply alliance can not be totally the same. Suppose the resource enterprise i costs in the supply chains is C_i , the coefficient of resource cost is β_i , the fine effect coefficient of each enterprise is α_i , q_i represents the profits divided by technological innovation , j is the motivate index of the enterprise to the technological innovation ;the coefficient of efforts level is k_i ;As the technological innovation, in the reference [14] we brings in the technological innovation factor.

a) *Calculate the resource investment rate of each enterprise taken up*

$$\beta_i = \frac{C_i}{\sum_{i=1}^{n} C_i}$$

b) *Calculate the percent of efficiency each took among all the enterprises*

$$\eta_i = \frac{\alpha_i}{\sum_{j=1}^{n} \alpha_j}$$

c) *Calculate the proportion of efforts level of each member in the alliance*

$$l_i = \frac{k_i}{\sum_{j=1}^{n} k_j}$$

d) *Calculate the technological innovation rate among all the members*

$$\xi_i = \frac{q_i}{\sum_{j=1}^{n} q_j}$$

C. Calculate the profits separately by taking every factor into account alone

$$v_i^1 = v_i\left(1+\left(R_i - \frac{1}{n}\right)\right) \quad (7)$$

$$v_i^2 = \left(1+\left(\beta_i - \frac{1}{n}\right)\right) \quad (8)$$

$$v_i^3 = v_i\left(1+\left(\eta_i - \frac{1}{n}\right)\right) \quad (9)$$

$$v_i^4 = v_i\left(1+\left(l_i - \frac{1}{n}\right)\right) \quad (10)$$

$$v_i^5 = v_i + j \cdot \sum_{i=1}^{n} q_i\left(\xi_i - \frac{1}{n}\right) \quad (11)$$

In the formulas: v_i represents the interests member i assigned using the traditional model of maximum entropy method ; v_i^2 stands for the profits distributed depended on the efficiency the member i contribute to the alliance; $\frac{1}{n}$ presents the average level of each factor.

D. Use AHP to calculate the weight of every factor

Finally take all the factors into overall consideration and use the AHP method to get the weight ω of every factor, then

$$\omega = (\omega_1, \omega_2, \omega_3, \omega_4, \omega_5) \qquad \sum_{i=1}^{5} \omega_i = 1 \quad (12)$$

So the modified maximum entropy method model integrated a variety of factors for the profits distributing in the supply chains, v_1' stands for the final profits enterprise i can get by the weighted summation :

$$v_i' = \omega_1 v_i^1 + \omega_2 v_i^2 + \omega_3 v_i^3 + \omega_4 v_i^4 + \omega_5 v_i^5 \quad (13)$$

The profits distribution of the supply chain should follow the principle "more risks, more profits" .So the enterprise who takes more risks should be distributed more profits. The equations above has presented the principle . In the equation (7) , if $R_i < \frac{1}{n}$, it means the risk enterprise i took in the supply chains is lower than the average level, which will reduce the profits enterprise i distributed , to the contrary it will increase.

V. CONCLUSION

In this paper, according to the characteristics of joint ventures, considering five aspects about each member's effort level, coefficient of efficiency, technological innovation, resources investment and risk , we use the improved maximum entropy method to build the mechanism of profit distribution among the joint ventures' members and a comprehensive consideration of the related factors is necessary, maximizing the benefit assignment fairness, impartiality and rationality, thus it ensures the stability of joint venture and cooperation. Compared with the assigned amount only by maximum entropy

method[14]or the Shapley value method, this thesis is taken more the subjective factors into consideration, therefor, it can obtain the distribution ratio easily which supply chain enterprises are satisfied. But this method has drawbacks: firstly, the process of using AHP for the weight of each factor to quantify is complex; secondly, with the increasing number of factors and consortium members, computation will be bigger, if the process can be analyzed by visualization programming, the thesis will be able to expand the scope of its application.

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