Modeling and Simulation of SCSA Performance under E-Commerce Environment

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***Abstract*—The performance evaluation of supply chain strategy alliance (SCSA) has the novelty compares with the traditional enterprise organization form under electronic commerce environment. This paper constructs a set of systematic SCSA evaluating indices system that included four aspects of customer and node enterprise satisfaction, supply chain operation flow, supply chain economic benefit, supply chain innovation and learning capability based on SCSA performance characteristic, uses the thought of balanced scoreboard and supply chain performance metrics reference mode1 (SCPR). Aiming at the problem of how to evaluate the SCSA performance, this paper proposes the data envelopment analysis (DEA) model based on chaos optimization (CO) algorithm, which not only can use the chaotic motion characteristics of the initial value sensitivity, the ergodicity, and the randomness, remove from the partial minimum point, but display the DEA's advantage of not involving the parameter estimation and weight determination, cause the evaluation results not influenced by the different index dimension. The SCSA performance evaluating results of 16 samples show that the model is simple and feasible, and improve the evaluating accuracy and efficiency.**

***Index Terms*—SCSA, improved DEA model, CO algorithm, performance evaluation, indices system**

I. INTRODUCTION

Along with the rapid development of information technology, electronic commerce and the supply chain unify closely day by day, which causes the supply and demand information more sharing, the business contact to be closer, the Omni-directional alliance cooperation among the enterprises becomes true feasible. Since the 1990s, some companies, such as IBM, Cisco, Dell, Wal-Mart and Nike, have started to construct the new organization form----supply chain strategy alliance (SCSA). The form of "the alliance" joins each enterprise node in together dynamically through the B to B electronic commerce technology. At present, the SCSA is substituting for the enterprise group and the strategy alliance, will become the organization development direction in the future.

Under the electronic commerce environment, the SCSA may make the bigger benefits, but its premise is to establish the effective alliance restraint and incentive mechanism. The basis of establishing this mechanism is the related data of supply chain overall performance evaluation. The optimized management of supply chain alliance under the electronic commerce environment brings to the problem of how to evaluate the alliance overall performance effectively.

At the present stage, the research about the SCSA is planted be in start level, the foundation is also quite weak, not forms the systemic research system yet. The existing literatures mainly concentrate on the SCSA construction and the risk investigation, the SCSA relations research and so on. But the literatures about the evaluating system construction of SCSA performance and the choice of the evaluating methods are still extremely rare. Therefore, it is urgent in the modern supply chain management domain to establish the complete SCSA evaluating system and evaluating method.

The SCSA performance is a systematic evaluating process, and a scientific and quantitative argumentation. There are some evaluating methods about the SCSA performance have been applied, such as: Delphi method, principal component analysis, analytic hierarchy process, fuzzy comprehensive evaluation method, etc. However, these methods are subject to stochastic factors in the evaluation, and the evaluating results are influenced by subjective experience and knowledge limitations easily, which often with personal bias and one-sidedness. With the development of artificial intelligence technology, the artificial neural network is used to the evaluating problems, and plays its advantages of approximation complex nonlinear systems and self-learning, self-

organizing and self-adapting ability, but it needs a lot of negative type data and experience knowledge. It is difficult to find a lot of negative type training samples in the process of evaluation, which will affect the accuracy and reliability of the evaluation. The data envelopment analysis (DEA) is proposed by A. Charnes and W.W. Cooper, and they proposed the first DEA model in 1978, the C^2R model. This initial form of he model is a fractional program, belongs to the non linear programming category. With the unceasing perfection of nonlinear theory and the rapid development of computer technology, the research about the complex nonlinear programming solving is being deepened unceasingly. The chaos optimization (CO) is a new optimization technique, which uses the chaos variable to carry on the chaos search directly, the search process carries on according to own rule and characteristic of the chaotic motion, and in all probability we can obtain the globally optimal solution for its intrinsic ergodicity and randomness. [1][2] This paper attempts to integrate the DEA and CO algorithm to evaluate the SCSA performance synthetically.

II. The Characteristic of SCSA Performance Evaluation

At present, although the SCSA performance has not an explicit definition, we may understand its connotation from the three aspects of the SCSA primary purpose, operation way and value enhancement way. The so-called SCSA performance is refer to the SCSA members to contribute their core competencies in the respective superiority domain for the alliance through the information sharing and coordinated operation, create or add value through the research and development, production-manufacturing, logistics management, market marketing and customer service, and so on. Compare with the traditional supply chain performance evaluation, under the electronic commerce environment, the characteristic of SCSA performance evaluation may mainly display in the following several aspects.

A. Emphasize the Separation of Management Performance, Supply Chain Performance and Electronic Commerce Performance

Under the electronic commerce environment, the performance evaluating of supply chain emphasizes the comprehensive capacity of the supply chain managers, including the knowledge, intelligence and innovation ability. It requests to differentiate the management performance and the supply chain performance, separate the management benefits from the electronic commerce function and the supply chain function. The evaluating beginning is to acknowledge the difference among the supply chain and the node enterprises. At present, the evaluating methods and practice of supply chain performance mix up the supply chain function, the person's effect mostly and the objective environment difference. It can lead to the unfair evaluation to the managers from the beginning. And it is also the main causes that lead to the difference between the important roles to enhance the enterprise competitive power and performance in the actual operation.

B. The Stronger Incentive and Restraint Function

Establish the effective evaluation system of performance management, take the just competition among supply chains with the similar function, strengthen the optimized supply chains, foster the developed supply chain according to the condition, abolish the supply chain of inferiors or the non-performance, evaluate the similar link performance in the identical supply chain, adopt the incentive or restraint according to the performance. Through the performance validity evaluation, we can define the valid contribution of participating enterprises or the departments to the entire supply chain management. Therefore, it is essential to develop the independent standard of supply chain performance, enhance the incentive and restraint function of the evaluating system to fit for the supply chain management under the electronic commerce circumstance.

C. Externality and Integrity

The SCSA performance evaluation emphasizes the information importance under the electronic commerce environment. At the same time, the evaluation pays great attention to the integrated benefits and the overall benefits of the node enterprises and the response level to the environment. Namely, under the electronic commerce environment, the SCSA performance evaluation attaches importance to the evaluating to the customer value, gives prominence to its externality and integrity.

D. Composability and Decomposability

Under the electronic commerce environment, the SCSA performance is the total value that be increased or created by the supply chain member through all kinds of activities, the value is composed of the customer value and the supply chain value, and each part may decompose the different value combination further. In the practical application, the user may select each kind of combination freely according to the evaluating goal and the concrete need; this can manifest that it is succinct and convenient fully.

E. Systematicness and Synthesis of the Evaluating Indices

Under the electronic commerce environment, the SCSA performance evaluation transfers from taking the cost as center to taking the diverse customer demand as center, pays close attention to the valid combination of the long-term development and the short-term profits, the mutual combination of the financial indices and the non-financial indices, realizes the systematicness and synthesis of the evaluating indices.

III. The Indices System of SCSA Performance Evaluation

A. The Construction Principles of the SCSA Performance Evaluation System

Compared with the performance evaluation of the traditional enterprises, the SCSA performance evaluation has its unique request: (1) Reflect organization's future expansibility and the forward feed of the performance management. Under the uncertain environment, we carry on the dynamic, real-time evaluation to the supply chain operation flow, simultaneously, must pay attention to the evaluation to the development of alliance enterprises and the long-term benefits. (2) Pay close attention to the balance of the interior operation and exterior chain. Besides carry on the basic evaluation to the enterprise interior operation, we must place the attention in the exterior chain control to guarantee the inside and outside consistent of the SCSA performance evaluation. (3) Lay equal stress on the non-financial indices and the financial indices. The SCSA performance evaluation should pay great attention to the valid combination of the long-term development and the short-term profits to realize effective transmission between the two goals. (4) Emphasize the integration of the performance evaluation. The evaluation should start from angle of the entire alliance, reflect the relatedness of various nodes enterprises or departments, and pay attention to the optimized operation of the entire supply chain.

Kaplan and Norton (1996) proposed the balanced scorecard theory. It thought that evaluate the enterprise's performance and incentive should analyze from four angles of the finance, the customer, the interior operate and study and growth. It requests that transfer the manage angle from the short-term goal to the strategic target, from reflection to the result to the cause monitoring. We learn the balanced scorecard thought, start from the mutual balanced of the finance, the customer, the interior operates and study and growth to design the SCSA evaluation system, may reflect strategic target of the whole supply chain alliance, satisfy the essential requirements of SCSA overall performance evaluation.

B. The Indices System of SCSA Performance Evaluation

This paper proposes that the indices system of the SCSA performance evaluation should include the four aspects of the customer and node enterprise satisfaction, supply chain operation flow, supply chain economic benefit, supply chain innovation and learning capability. The evaluating index system is as shown in Table I.

TABLE I.
THE EVALUATING INDICES SYSTEM OF SCSA PERFORMANCE

Objective Layer Y	1 Class Index X	2 Class Index Z
The indices system of SCSA performance evaluation Y	Customer and node enterprise satisfaction X_1	Product quality Z_{11}
		Service level Z_{12}
		Delivery time Z_{13}
		Information communication Z_{14}
		Efficiency Z_{15}
		Punctual delivery rate Z_{16}
		Qualified rate of product quality Z_{17}
		Information communication level Z_{18}
	Operation flow X_2	Output flexibility Z_{21}
		Delivery flexibility Z_{22}
		Production and distribution rate Z_{23}
		Production and demand rate Z_{24}
		Data sharing rate Z_{25}
	Economic benefit X_3	Profit increment rate Z_{31}
		Market sharing rate Z_{32}
		Cost reduction rate of compared product Z_{33}
		Capital returns ratio Z_{34}
		Turn of capital Z_{35}
	Innovation and learning capability X_4	Intelligence capital ratio Z_{41}
		Average training time Z_{42}
		Average training expense Z_{43}
		Invests market time of new product Z_{44}
		Sale ratio of new product Z_{45}

1) The evaluation of the customer and node enterprise satisfaction

a) The customer satisfaction evaluation

The customer value is the important component of the integrated supply chain overall performance, but the customer satisfaction degree is the concentrated reflection of customer value. We evaluate the customer satisfaction degree through the questionnaire way (Table II). Suppose the option value is: very satisfied=+2, satisfied=+1, general=0, bad=-1, very bad=-2. The formula is:

Customer satisfaction degree=Σ evaluation value / (2× investigation number)

TABLE II.
THE QUESTIONNAIRE SURVEY FORM OF CUSTOMER SATISFACTION

Item	Very Satisfied	Satisfied	General	Bad	Very Bad
Product quality					
Service level					
Delivery time					
Information communication					
Efficiency					

b) The node enterprise satisfaction evaluation

This index reflects the relations between the upstream and the downstream node enterprise of the supply chain, namely the satisfaction degree of the downstream enterprise to its neighboring upstream enterprise over a period of time. The specific indices are as follows:

The punctual delivery rate (Z_{16}) is refers to the punctual delivery times divided by the total delivery times of the supply chain node enterprises over a period of time. The index value is high, shows that the productivity and the management level is high in the upstream enterprises. The formula is:

Punctual delivery times of upstream enterprises / total delivery times ×100%

Qualified rate of product quality (Z_{17}) is refers to the qualified products provided by the various nodes of the supply chain divided by the total products, the index value is lower, shows that the worse product quality of the node enterprise. It will delay the delivery date, increase the total cost and affect its cost-profit ratio. The formula is:

Qualified products / total products ×100%

The information communication level (Z_{18}) is used the expert scoring to evaluate the information communicate degree between the upstream and the downstream node enterprise. The division method is: information

communication level = (fine, medium, bad) = (5, 3, 1). After obtaining the rank value, each value divided by 5, changed into the answer value of the [0, 1].

2) The operation flow evaluation of the supply chain

The index reflects the cooperation close degree of the SCSA neighboring node enterprise. It includes the following specific indices:

The output flexible index (Z_{21}) reflects the adjustment capacity of the output levels when the customers demand changes. Suppose the customer demand d is the random variable obeying the normal distribution, namely $d \sim N(\mu, \delta^2)$, we define the Q_{min} and Q_{max} as the minimum and maximum output separately; Suppose d is the customer demand in the t period, N is the period times, then the formula of the average demand (d') is as follows:

$$d' = \sum_{i=1}^{N} d_t / N_i$$

Demand variance is:

$$s^2{}_d = \sum_{i=1}^{N} (d_i - d')/N - 1$$

The output flexibility (F1) reflects the probability that customer demand falls to the output scope, the formula is:

$$F1 = P(Q_{\min} \le d \le Q_{\max})$$

Transforms:

$$F1 = \phi[(Q_{\max} d')/s_d] - \phi[(Q_{\min} d')/s_d]$$

The delivery flexibility (Z_{22}) reflects the ability when the enterprise node changes the plan delivery date, suppose the enterprise node t* is the data to accept the order. L_m represents the latest completion time of m^{th} work (m=l, 2,…, N), E_m represents the earliest completion time of m^{th} work, then the formula of delivery flexibility is:

$$F2 = \sum_{m=1}^{N} (L_m - E_m) / \sum_{m=1}^{N} (L_m - t^*)$$

The production and distribution rate (Z_{23}) is the divided by the finished products of the various nodes of the SCSA. The formula is:

Already sold products / finished product amounts ×100%

The production and demand rate (Z_{24}) is the finished product amounts of the SCSA node divided by product demand of the downstream node; the index reflects the supply and demand relation among the various nodes. The formula is:

Node output / node demand of amounts downstream enterprise ×100%

Data sharing rate (Z_{25}) is the sharing data quantity divided by the total data quantity in the SCSA organization. Information sharing content includes the demand prediction, sale point data, productive plan, strategic direction, customer goal and so on. The formula is:

The data sharing rate = sharing data quantity / total data quantity ×100%

3) The economic benefit evaluation of the supply chain

We should evaluate the economic efficiency of the SCSA from the four aspects of the rentability, the security, the fluidity and the growth. The specific indices are including the profit increment rate (Z_{31}), the market sharing rate (Z_{32}), and the cost reduction rate of compared product (Z_{33}). The formula is:

Profit increment rate (Z_{31}) = (profit of current period – last period profit)/ last period profit ×100%

Market sharing rate (Z_{32}) = product amounts provided by this supply chain / product amounts provided by the similar enterprises ×100%

Cost reduction rate of compared product (Z_{33}) = (similar products cost of last period–similar products cost of this period) / similar products cost of last period ×100%

Capital returns ratio (Z_{34}) is the customer profits divided by the used average assets of the SCSA in the period. It reflected the accrued performance after using the alliance assets. The formula is:

Supply chain customer profits / supply chain average assets ×100%

Turn of capital (Z_{35}) is the capital turnover amounts in the SCSA divided by the capital average occupancy amounts in a certain period. The formula is:

Capital turnover amounts / capital average occupancy amounts×100%

4) The innovation and learning capability evaluation of the supply chain

The innovation and development ability of the supply chain is the concrete manifestation of the SCSA core competitiveness, and is also the basic guarantee of enterprise prosperous and progress.

Intelligence capital ratio (Z_{41}) is refers to the percentage of the intangible asset and the human resources value in the total assets of the supply chain enterprise. The formula is:

The intangible asset and the human resources value / total assets of the supply chain enterprise ×100%

Average training time (Z_{42}), average training expense (Z_{43}) is refers to the total person hour that the employees accepted the training in a period of time divided by the total costs and the total employees. It reflects the importance degree to the regular training in the supply chain enterprises. And it is also important to the future sustainable development ability of the supply chain enterprises.

Average training time = Σ (training time × training employees)/total employees×100%

Average training expense = total training costs / total employees ×100%

Invests market time of new product (Z_{44}) reflects the competitive ability of the supply chain (enterprises) to hold the market opportunity and make the rapid reaction to the market demand. The time to be shorter, the ability is stronger.

Sale ratio of new product (Z_{45}) is refers to the sales of the new product or service in a period of time divided by the gross sales in the supply chain enterprises. The formula is:

Sales of the new product or service in a period of time / gross sales in the same period ×100% [3]-[6]

IV. THE SCSA PERFORMANCE EVALUATING MODEL BASED ON IMPROVED DEA AND CO ALGORITHM

A. The Basic Principle of CO Algorithm

The chaos is a kind of universal phenomenon exists in nonlinear system, the chaos is not the confusion, but a kind of phenomenon has the fine intrinsic structure. The chaotic motion has the characteristics of ergodicity, randomness, and regularity, the chaotic motion can traversal all the conditions in certain scope according to its own rule. Therefore, it will have the superiority compared to the random search if we carry on the optimized search using the chaos variable.

The search process of the chaos optimization method divides into first carrier and second carrier. First carrier process carries on the global optimization search using the chaotic motion's ergodicity, enlarges the chaos variable's traversal interval to the definition domain of optimized variable through the appropriate carrier way simultaneously; Second carrier process carries on the partial search though the chaos perturbation based on the inferior optimal solution which obtains by first carrier. Looked from the search process of chaos optimization method, first carrier is the foundation of second carrier, and first carrier is very important in the entire CO algorithm. If the search interval is not big, first carrier often could find the optimal solution quite easily; if the search interval is big, although the chaos variable can achieve the optimal solution theoretically, but it needs the very long time to find the inferior optimal solution. The function of second carrier is to realize the refined search nearby the inferior optimal solution through the additional chaos perturbation. Second carrier coefficient reflects the scope of chaos perturbation. Through the self-adapting adjustment of second carrier based on the inferior optimal solution of first carrier, we can improve the search speed and the optimization precision of the CO algorithm. [7][8]

B. DEA Evaluating Model Construction Based on CO Algorithm

1) Intruduation to the basic DEA theory

Farrell proposed the production efficiency measurement method when he carries on the analysis to the British agriculture production capability in 1957. He replaced "the preinstall function" by "the non-preinstall production function" to estimate the efficiency value, and determined the front line of the efficiency using the mathematical programming. This may be regarded as the prototype of the DEA. The DEA was proposed by A.Charnes, W.W.Cooper, and E.Rhodes, the famous operational research experts officially in 1978. Its core thought is to evaluate the relative validity between the many input and output "units" or "departments", which is called decision-making unit (DMU) through the mathematical programming to seek the optimal solution. The basic characteristic of DEA method is to measure the relative DMU efficiency using the effective leading surface of production possible collection composed by the DMU input and output data, therefore this method does not involve the parameter estimation and the weight determination, the different index dimension can't influence the evaluation results. The C^2R model is the earliest DEA model, its basic principle is as follows:

$$\begin{cases} \max = \sum_{r=1}^{s} u_r y_r \Big/ \sum_{i=1}^{m} v_i x_i = \eta \\ s.t.h_j = \sum_{r=1}^{s} u_r y_r \Big/ \sum_{i=1}^{m} v_i x_i \le 1 \\ v = (v_1, v_2, \cdots, v_m)^T \ge 0 \\ u = (u_1, u_2, \cdots, u_s)^T \ge 0 \end{cases} \tag{1}$$

This model also may be express by the matrix as follows, it is a fractional program.

$$\begin{cases} \max v^T y_j \ge 0 \\ s.t. w^T x_j - v^T Y_j \ge 0 \quad (j = 1,2,\cdots,) \\ w^T X_{j0} = 1 \end{cases} \tag{2}$$

2) C^2GS^2 Model

$$\begin{array}{cccccccccc} & & 1 & 2 & & j & & n & DMU & \\ V_1 & \rightarrow & x_{11} & x_{12} & ..... & x_{1j} & ..... & x_{1n} & & \\ V_2 & \rightarrow & x_{21} & x_{22} & ..... & x_{2j} & ..... & x_{2n} & & \\ & & & ..... & & ..... & & & & \\ V_n & \rightarrow & x_{m1} & x_{m2} & ..... & x_{mj} & ..... & x_{mn} & & \\ & & y_{11} & y_{12} & ..... & y_{1j} & ..... & y_{1n} & \rightarrow u_1 & output \\ & & y_{21} & y_{22} & ..... & y_{2j} & ..... & y_{2n} & \rightarrow u_2 & \\ & & & ..... & & ..... & & & & \\ & & y_{s1} & y_{s2} & ..... & y_{sj} & ..... & y_{sn} & \rightarrow u_n & \end{array} \tag{3}$$

Suppose the DMU input is $X=(X_1,X_2,X_3\ldots,X_n)^T$, the output is $Y=(Y_1,Y_2,Y_3\ldots,Y_n)^T$, (X,Y) shows production activity, consider several DMU, the corresponding production activities are (X_j,Y_j), j=1,2, …,n. In which: x_{ij} is the inputs total amount that the j^{th} DMU corresponding the i^{th} type input, ($x_{ij}>0$); y_{rj} is the outputs total amount that the j^{th} DMU corresponding the r^{th} type output, ($y_{rj}>0$); v_i is the i^{th} type input weight; u_r is the r^{th} type output weight; (i=1,2,3, …,m; r=1,2,3, …,s; j=1,2,3, …,n).

x_{ij} and y_{rj} are known data, v_i and u_r and variable, corresponding to the weights $v=(v_1,v_2,\ldots,v_m)^T$, $u=(u_1,u_2,\ldots,u_s)^T$, v and u is variable, the j_0 DMU efficiency index as targets, all DMU's efficiency indices as binding, ($h_j\le1$,j=1,2,3, …,n), the optimal model are as follows:

$$\begin{cases} \max = \dfrac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \\ s.t. = \dfrac{\sum_{r=1}^{s} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \le 1 \\ j = 1,2,\cdots,n \\ v = (v_1, v_2, \cdots, v_m)^T \ge 0 \\ u = (u_1, u_2, \cdots, u_s)^T \ge 0 \end{cases} \tag{4}$$

Order:

$$t=\frac{1}{v^t x_0}, \omega=tv, \mu=tu$$

The formula (4) transforms into:

$$(P)\begin{cases}\max \mu^T y_0 = V \\ s.t.\begin{cases}\omega^T x_j - \mu^T y_j \geq 0 \\ \omega^T x_0 = 1 \\ \omega \geq 0, \mu \geq 0\end{cases}\end{cases} \quad (5)$$

The formula (5) is the traditional C^2R model, which lack of accuracy on certain occasions.

C^2GS^2 model can evaluate the technology effectiveness among the department; the production possible set T is a multi-convex surface set, which is decided by the convex, the invalid and the smallest assumption of the production possible set justice system. At this point the production frontier can be seen as production function concept's popularization under the multi-outputs circumstances. [9]-[15]

It's difficult to determine whether exist the optimal solution, use Archimedes infinitesimal ε, solve through using the linear programming simplex method, and then determine the DMU's DEA validity, the C^2GS^2 model is as the formula (6):

$$(P\in)\begin{cases}\max(\mu^T y_0 + \mu_0) = V(\in), \\ s.t.\begin{cases}\omega^T x_j - \mu^T y_j - \mu_0 \geq 0, \\ \omega^T x_0 = 1 \\ \omega^T \geq \in \bullet e^T \\ \mu^T \geq \in \bullet e^T\end{cases}\end{cases} \quad (6)$$

Its linear programming dual problem is:

$$(D\in)\begin{cases}\min[\theta - \in (e^T s^- + e^T s^+) = V_D(\in), \\ s.t.\begin{cases}s.t.\sum_{j=1}^{n} x_j \lambda_j + s^- = \theta x_0, \\ \sum_{j=1}^{n} y_j \lambda_j + s^+ = y_0 \\ \sum_{j=1}^{n} \lambda_j = 1, \\ \lambda_j \geq 0, \\ s^- \geq 0, s^+ \geq 0\end{cases}\end{cases} \quad (7)$$

The optimal solution VD(ε)≤1, θ(θ≤1) is technology effectiveness indicators evaluating DMU^0, the greater θ is, the better technology effectiveness.

To the model, the corresponding linear programming economic explanation is: in the production possible set T, when output y_0 remains unchanged, should lower input x_0 according to the same percentage θ reduction, if not, the optimal value VD(ε)= θ^0=1, under the single-input and single-output circumstances, DUM j_0 is "technology effectiveness".

3) DEA evaluating model construction optimized by CO algorithm

Suppose the n similar departments, are called decision-making unit, each DMU has m input and s output. And $x_j=(x_{1j}, \cdots, x_{ij}, \cdots, x_{mj})^T$ is the input of j^{th} DMU, $y_j=(y_{1j}, \cdots, y_{rj}, \cdots, y_{sj})^T$ is the output of j^{th} DMU; x_{ij} is the i^{th} input of the j^{th} DMU, $x_{ij}>0$; y_{rj} is the r^{th} output of the j^{th} DMU, $y_{rj}>0$; v_i is a kind of measurement of the i^{th} input, u_r is a kind of measurement of the r^{th} output, i=1, …, m, r=1, …, s. x_{ij}, y_{rj} are the known data, may obtain according to the historic information; v_i, u_r are the variable.

Define the efficiency evaluation index of j^{th} DMU corresponding to a group of weight coefficient $V=(V_1, V_2, \ldots, V_m)^T$, $U=(U_1, U_2, \ldots, U_s)^T$:

$$h_j = \sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{m} v_i x_{ij} \quad (8)$$

Selects weight coefficient u_r and v_i, which meet:

$h_j \leqslant 1$ (j=1, 2, …, n) (9)

Carry on the efficiency evaluation to the j_0^{th} DMU ($1 \leqslant j_0 \leqslant n$), take the u_r and v_i as change vectors, take the efficiency index of j_0^{th} DMU as the goal, take the efficiency index of all DMU as the restraint. Construct the following optimized model:

$$\begin{cases}\max\ h_{j_0} = \sum_{r=1}^{s} u_r y_{rj_0} \Big/ \sum_{i=1}^{m} v_i x_{ij_0} \\ s.t. = \sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{m} v_i x_{ij} \\ u_r \geq 0, v_i \geq 0\end{cases} (j=1,2,\cdots,n) \quad (10)$$

Formula (10) is a fractional program, belongs to the nonlinear programming. With the rapid development of nonlinear system and computer technology, many effective nonlinear optimization algorithms appeared. The CO algorithm can improve the operation efficiency, avoid to falling into the partial optimum point, and obtain the globally optimal solution using the iteration non-duplication and the ergodicity. Because the DEA model has the complex restraint and non-linearity, this paper proposes the algorithm that tumbles the feasible zone of the constrained problem to the chaos second carrier process.

To utilize the chaos algorithm to solve, we transform the formula (10) into the standard form:

$$\begin{cases}\max\ h_{j_0} = \sum_{r=1}^{s} u_r y_{rj_0} \Big/ \sum_{i=1}^{m} v_i x_{ij_0} \\ s.t. = 1 - \sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{m} v_i x_{ij} \\ u_r \geq 0, v_i \geq 0\end{cases} (j=1,2,\cdots,n) \quad (11)$$

Suppose the dimension of independent variable X is s+m, $X=[x_1, x_2, \ldots, x_{s+m}]$, $xi \in [d_i, e_i]$, the first s items of X represent u_r(r=1,2…, s), the latter m items represent v_i(i=1,2, …, m). We record the objective function as f(X), record the constraint condition as $g(X) \geqslant 0$. The basic step of CO algorithm to solve the formula (11) is as follows: Chaos optimization method solution type (11) is:

Step 1 Initialization the algorithm. Set k=1, generate s+m initial value randomly, $x_{i,k}$, i=1, …, s+m.

Set $x'_{i,k}=d_i+(e_i-d_i)x_{i,k}$ (12)

Make $X^*=X'_k$, $f^*=f(X^*)$ when the constitution vector $X'_k \in S(S=\{X \mid g_i(X)\geqslant 0, i=1, 2, \cdots m\})$, otherwise repeat the Step 1 until obtain X_k, and cause X'_k to meet the constraints.

Step 2 Set the biggest iterative times N. Set the X_1 to $x_{k+1}=\lambda x_k$ $(1-x_k)$ ($x_k \in [0, 1]$, K=4.0), generate the chaos vector sequence $\{X_k\}k=2, 3, \cdots, n$, carry on the carrier wave according to the formula (12), and we can obtain the feasible examination of X'_k.

If $f(X'_k) < f(X^*)$

Then $X^*=X'_k$, $f(X^*)=f(X'_k)$

Otherwise, set k=k+1, carry on the examination to X'_{k+1}, and repeat the Step 2 until $f(X^*)$ value only has the small change, or satisfy the biggest iterative times.

Step 3 Set the cycle index. Carry on the second carrier wave according formula (13), Set $Z_k=X^*$, Z'_{k+1} is the chaos sequence generated by the Logistic mapping. Set $\alpha=0.0001(e'-d')$, the coefficient may be decided according to the concrete question.

$Z_{k+1}=Z_k+\alpha Z_{k+1}$ (13)

Carry on the examination to Z_{k+1}, if pass the examination, when $f(Z_{k+1})<f(Z_k)$, Then $Z_k=Z_{k+1}$, $f(Z_k)=f(Z_{k+1})$; Otherwise, set k=k+1, repeat the Step 3, until the $f(Z_k)$ value satisfy to meet the accuracy requirement or the biggest iterative times. The final Z_k is the asked solution, the corresponding $f(Z_k)$ is the optimum value. [16]-[20]

V. SIMULATION EXPERIMENT

In this paper, we take the SCSA performance evaluation based on DEA and CO Algorithm of 16 samples as an example, the input and output data is shown in table III.

We unify the DEA model and CO algorithm, take the X_1, X_2, X_3, X_4 as the input value of the DEA model, and select the Tobin Q value (Y_1), the SCSA performance(Y_2) as output value. According to the data in Table III, we carry on the Q cluster analysis to the 16 DMU according to comprehensive SCSA performance θ*, the operation flow and economic benefit of the supply chain δ*, the innovation and learning capability of the supply chain s*, and measure the SCSA performance of the different samples, the evaluation results are shown as Table IV and Table V. We can obtain that the SCSA performance of DMU4, DMU 14, and DMU 1 is very high, the SCSA performance of DMU2, DMU11, DMU10, DMU9 is high, the SCSA performance of DMU3, DMU5, DMU6, DMU8, DMU12, DMU13, DMU16 is general, and the SCSA performance of DMU15, DMU7 is bad.

TABLE III.
THE DEA INPUT-OUTPUT DATA OF SCSA PERFORMANCE EVALUATION

No.	Input Index				Output Index	
	X_1	X_2	X_3	X_4	Y_1	Y_2
1	61.63	27.27	28.61	11	6.74	2.37
2	76.64	33.33	33.61	9	12.50	1.90
3	64.51	33.33	63.12	9	9.07	1.48
4	60.19	33.33	50.98	9	27.52	2.27
5	63.26	36.36	54.25	11	7.16	1.75
6	70.87	33.33	21.14	12	2.43	1.07
7	81.06	66.67	67.37	12	1.58	1.38
8	80.33	38.46	60.82	13	6.35	0.98
9	52.05	42.86	46.39	7	9.63	1.51
10	58.22	33.33	26.48	15	5.21	1.56
11	63.49	30.76	52.62	13	16.41	1.50
12	41.29	28.57	34.08	14	3.53	1.03
13	82.69	61.54	42.93	13	8.63	1.90
14	57.98	44.44	20.05	9	9.16	2.21
15	71.57	33.33	31.77	15	0.84	1.29
16	71.34	33.33	70.65	12	8.51	1.74

TABLE IV.
THE SOLUTION RESULTS OF SCSA PERFORMANCE EVALUATION

DMU	θ*	δ*	s*	$\sum\lambda_i$*	SCSA
1	1	1	1	1	Constant
2	0.861115	1	0.861115	0.813365	Increasing
3	0.519494	1	0.519494	0.519494	Increasing
4	1	1	1	1	Constant
5	0.574861	0.869565	0.661090	0.62712	Increasing
6	0.525302	1	0.525302	0.46993	Increasing
7	0.357070	0.628402	0.568219	0.476094	Increasing
8	0.297775	0.77842	0.382538	0.352574	Increasing
9	0.666586	1	0.666586	0.518455	Increasing
10	0.681132	0.921191	0.739402	0.677344	Increasing
11	0.670834	0.935142	0.717361	0.647018	Increasing
12	0.499876	1	0.499876	0.429956	Increasing
13	0.478159	0.854131	0.559819	0.548188	Increasing
14	1	1	1	1	Constant
15	0.556721	0.667657	0.833843	0.804154	Increasing
16	0.544543	0.869565	0.626225	0.555032	Increasing

TABLE V.
THE OPERATION RESULTS OF SLACK VARIABLE S_i^- AND S_R^+

DMU	S_1-	S_2-	S_3-
1	0	0	0
2	0	16.779755	0
3	5.098981	0	0
4	0	0	0
5	0	0	0.679381
6	0	9.264050	1.681078
7	0.276029	0	0
8	0	0.705833	0.599268
9	20280235	0	0
10	0	0	3.350075
11	1.255635	2.878921	2.562257
12	0	0	3.112500
13	0	0.647048	1.257400
14	0	0	0
15	0	0	0
16	6.455694	0	1.413323

CONTINUED TABLE

DMU	S_4-		
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	1.227017	0.051613	0
6	0	0	1.398823
7	7.937663	0	4.092155
8	0	0	0
9	11.28974	0	0

10	0	0	0.075147
11	0	0	0
12	0	0	0.747696
13	0	0	2.994036
14	0	0	0
15	1.799145	0	0
16	0	0	0

VI. CONCLUSION

The chaos optimization is a new direction of the chaos applied research; it carries on the optimized search using the motion law of the chaos variable, and has the possibility to flee the partial minimum point. The basic feature of DEA method is to measure the relative DMU efficiency using the effective leading surface of production possible collection composed by the DMU input and output data, therefore this method does not involve the parameter estimation and the weight determination, the different index dimension can't influence the evaluation results. This paper integrates the DEA and the CO algorithm to evaluate the SCSA performance, and obtains the ideal result. It indicated that we can use the optimized algorithm to solve the fractional program problem of the DEA method with the gradual perfection of the non-linearity theory. But the different evaluating indices will result in the different evaluating results using the DEA method; there is not the recognized index selection criterion at present, so it needs to study further.

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