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Partner Selection Problem of Supply Chain Alliance based on Plant Growth Simulation Algorithm

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ABSTRACT. *In order to solve partner selection problem of supply chain alliance, on the base of constructing a multi-objective decision model of partner selection problem, an optimal solution which is called plant growth simulation algorithm for target function is proposed. By setting reasonable parameter value of plant growth simulation algorithm, and calculating on the real instance, the result shows that the proposed solution algorithm not only has a better calculating performance, but also has a faster rate of convergence and stability to the overall optimum.*

Keywords: Supply Chain Alliance; Partner Selection; Multi-Objective Decision Model; Plant Growth Simulation Algorithm

1. Introduction. Nowadays, with the accelerating process of economic globalization, product varieties are increasing gradually, and the life cycle of products are gradually shorter. Customers are more and more strict to the delivery requirements, and expectations to the product and service are getting higher and higher. In order to make quick and rational response to the constantly changing market and customer demand promptly, more and more enterprises have started to change their enterprise resources integration model from self-inside integrated model to internal-external resources optimization supply chain alliance model, and the competition accordingly change from pure quality of product competition up to the competition between the entire supply chain. Supply Chain (SC) is a value increment chain which is consisted by raw material suppliers, spare parts suppliers, manufacturers, distributors, retailers, transportation operators and so on, product will finally delivered to the customer from original raw material to the finished product along each enterprise of the chain (Rui Hua, 2007). Supply Chain Alliance is a new form of business organized configuration under the increasingly fierce market competition environment. It is composed by certain mutually independent companies, these companies have the same common goal or benefit to achieve. The core company coordinates and controls information flows, logistics flows, capital flows, knowledge flows, service flows between related partners in the chain, and a series of business events such like product design, raw material procurement, product manufacturing, packaging, sales, service and so on are all covered , therefore a high-low business related, supply, manufacturing, consumer integrated, and meet customer needs with lowest cost completed network is formed. Each enterprise of the supply chain have their own good and advantages in different aspects of design, production, manufacturing, sales. It can not only help to reduce the total cost of the entire supply chain and inventory levels by the cooperation, and produce a greater competitive

advantage through information sharing, interactive exchange, advantage complement each other, but also can help enterprises of the supply chain share risks and interests altogether. Because it is not an easy thing to choose the most suitable cooperation partners best for the operation of supply chain from numerous candidates, therefore, the optimization of partner selection problem has become an important core issue in supply chain system, the problem's result directly affects the quality and performance of the whole supply chain operations, a reasonable selection of partners will help companies reduce costs, increase flexibility, improve competitiveness, and decrease existing risks. Therefore, studying on how to select and construct partnership evaluation criteria system has a very important reality research significance. It make the optimal decision by using effective decision-making methods and tools among numerous candidate partner companies, to ensure that the entire supply chain alliances operation is efficient and economic.

Plant Growth Simulation Algorithm (PGSA) is a new type of intelligent optimization algorithm after Genetic Algorithm (GA), Ant Colony Algorithm (AA), Simulated Annealing Algorithm (SA) and other evolutionary algorithms, this algorithm is based on a computer system (namely L-systems) which is proposed by A. Lindenmayer and P. Prusinkiewicz et al. in the 1990s. L-system is used in the fractal domain and the computer graphics to simulate the plant growing and branching process. Undergoing a long-term and the massive research, people discovered that in the plant growing process, the branches and leaves growing speeds have a direct relation with the light source intensity. The complex growing process of plant can be abstracted into a kind of phototropism growing dynamic competition model, which simulates the plant growth from seed germination, until the plant cover the whole growth process space. Compared with other optimization algorithms, PGSA have many characteristics such as fewer parameters, easily coding and implement, fast calculating speed, no more restrictions or requirements in solving the goal function and so on. There are few studies on the application of PGSA at present, only minority scholars have done some research on it, and the applied scope mainly concentrates in the electrical network optimizations. This paper takes partner selection problem of supply chain as research aim, constructs a mathematical model of the problem by considering various factors. On this basis, proposes take use of PGSA to solve the model, by calculating real instance, the result shows the effectiveness and stability of this method.

At present, many domestic and foreign scholars have done some researches in the partner selection problem of supply chain alliance, the existing related literatures contain both qualitative research and quantitative research. The qualitative methods mainly include the intuitive judging method, the tender selection method, negotiation method and so on; the quantitative methods mainly contain linear weighting method, statistical method, AHP, TOPSIS method, ABC cost method, neural network method, mathematical programming, cluster analysis method and so on. Dickson analyzed and obtained 23 supplier evaluation indicators after investigating 170 purchases, he also classified the importance of each indicator, which, quality, date of delivery, past performance are considered to be three most important indicators in selecting suppliers (Dickson,1966). Caddick (Caddick and Dale, 1987), Weber (Weber, 1991), symtka (Symtka and Clemens,1993), Patton(Patton,1996) et al. had done some deeper research on this basis； Mohammad et al. designs and implements a procedure for judging the suitability of suppliers for an organization competing on agile

manufacturing characteristics, and applies analytical network process and data envelopment analysis in a multi-phased supplier selection approach(Mohammad, Ravi and Joseph, 2008). JG Martin Proposes an alternative decision support system (namely VIG)(JG Martin, 2007); Ying Dai proposes a self-adaptive genetic algorithm to optimize partner selection in a supply chain alliance, in the genetic algorithm ,each member in a supply chain alliance has a self-adaptive ability to changes in environment in the genetic process through designing crossover probability and mutation probability(Ying Dai, 2004); Jianguo Jiang , Na Xia et al. adopts ant colony optimization to solve the partner selection problem , during the process of this solution, ants incline to choose those enterprise who cooperated well before to form supply chains, and the "self-adaptive perturbation mechanism" can avoid the prematurity of the algorithm(Jianguo Jiang & Na Xia , 2006); Haiyong Liu et al. presents a new quantum particle swarm optimizer called the cooperative evolutionary QPSO with multi-populations for solving partner selection of agile supply chains. The whole quantum particle swarm group is divided into several subgroup evolved independently and updated sharing information periodically(Haiyong Liu, Yongqian Zheng and Shuqiang Song , 2009); Ping Wang promotes a review of regarding the forming of supply chain as a process of evolution networks and builds up a simulation model based on system dynamics to solve the problem of selection of cooperation partner(Ping Wang, 2010); Rui Zhang et al. adopts immune genetic algorithm to solve the problem, and presents the immune genetic algorithm based agile supply chain partner selection algorithms, its immune mechanism can avoid the phenomenon of premature in some extent, improve the global searching capability, and enhance the convergence velocity (Rui Zhang, Na Xia and Guofu Zhang, 2006). But among these methods, some are insufficient of considering both subjectivity and objectivity, the fit and unfit quality evaluation can not very clearly discriminated, and the methods or models are lack of compatibility and scientificalness; some because of involving a large number of candidates and evaluating indicators, decision-makers can't determine certainty sometime , using the general method can not get the solution; and some methods are too complex to computing and difficult to implement, to obtain exact optimal solution is not easy.

2. Problem Description and Mathematical Model. We Assuming there are n tasks need to be completed in the supply chain operation, the tasks can be expressed as: $T = \{t_i \mid i \in [1, n]\}$; mi candidate partners who are able to undertake the task ti, then the candidates to complete each task ti can be expressed as: $P_i = \{p_{ij} \mid j \in [1, m_i]\}$ (i = 1, 2 ,..., n). Partner selection problem of supply chain alliance can be described as: a supply chain alliance has n tasks to be done, there are several candidate companies to choose for completing each task, each candidate company hope to join the supply chain and take one task to complete, the goal is to find out the most suitable partner company for each task, which can make the overall operation of the entire supply chain achieve the optimal performance.

The performance evaluation of partner selection can be indicated by a group of performance indicators $V_{e_{ij}} = \{t_{e_{ij}}, c_{e_{ij}}, q_{e_{ij}}, r_{e_{ij}}, ...\}$. Among them, $t_{e_{ij}}$ indicates the time index, $c_{e_{ij}}$ indicates the cost index, $q_{e_{ij}}$ indicates the quality index, $r_{e_{ij}}$ indicates the reliability index, it also can choose other performance parameters according to the actual situation, then

assigns T, C, Q, R, D, respectively indicate the total time, cost, quality, reliability and link cost of all completed tasks; supposing $d_{ij,vq}$ indicates the link cost between enterprise e_{ij} and e_{vq}, fn is a group of selected enterprises that undertake the ith sub-task, then the optimizing object of partner selection problem is to select out a group of companies $F=\{f_1, f_2,..., f_n\}$, which satisfies:

$$\min T, \min C, \max Q, \max R, \min D \tag{1}$$

Obviously, the problem is a multi-objective optimization problem. The objective function can be further expressed as follows:

$$\min Z = w_1 T + w_2 C + w_3 Q' + w_4 R' + w_5 D \tag{2}$$

Here, w_k expresses weight, and $\sum_{k=1}^{5} w_k = 1$. The value of w_k can be set by expert grading method, analytic hierarchy method, entropy method etc., assuming $u_{ij} = \begin{cases} 1, \mathrm{e_{ij}\ is\ seleted} \\ 0, \mathrm{otherwise} \end{cases}$, then in formula (2) there are:

$$T = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \frac{t_{e_{ij}}}{t_{\max}} \bullet u_{ij} \tag{3}$$

$$C = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \frac{c_{e_{ij}}}{c_{\max}} \bullet u_{ij} \tag{4}$$

$$Q' = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \left(1 - \frac{q_{e_{ij}}}{q_{\max}} \right) \bullet u_{ij} \tag{5}$$

$$R' = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \left(1 - \frac{r_{e_{ij}}}{r_{\max}} \right) \bullet u_{ij} \tag{6}$$

$$D = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \sum_{q=1}^{m_{i+1}} \frac{d_{ij \bullet (i+1)q}}{d_{\max}} \bullet u_{ij} \bullet u_{(i+1)q} \tag{7}$$

here, $t_{\max}, c_{\max}, q_{\max}, r_{\max}, d_{\max}$ express the performance parameter maximum value of completing various tasks of all candidate companies.

3. Algorithm. When plant outgrows, the main drive to promote its growth impetus comes from the sunlight, the morphactin concentrations in plant are changed with photosynthesis, the point which has received sufficient sunlight with more concentrations will grow prior. By using plant growth simulation algorithm to solve optimization problems is actually a simulation process of plant outgrowing to the whole space. According to the internal driving force of plant growth and force of the phototropism and the dynamics mechanism of stems, branches and withered, the whole growing space is regarded as the possible solutions' domain, light source is regarded as the global optimal solution. From the concentration theory of botany perspective to establish a dynamic model towards the light source in the overall best way (Tong Li , Chunfeng Wang and Wenbo Wang, 2005).

3.1 Dynamic Mechanism of PGSA. The point which can outgrow a new branch in the plant stem or vine stems is called growing point, the more morphactin concentration of the growing point, the more growing opportunities it gets. The morphactin concentration of plant is mainly decided by phototropic, it will be reassigned among each growing points if

the environment location is changed. Tong Li analyses the probability growth model of simulating the plant’s phototropic, and gives out morphactin concentration calculating formulas of the stems and branches. Assuming M is stem length, there are K initial points in the stem, expresses as SM = (SM1, SM2 ,..., SMK), and their respective morphactin concentrations are PM = (PM1, PM2 ,..., PMK); within the unit of length m (m <N) there are Sm= (Sm1,Sm2,...,Smq) growing points, and their respective morphactin concentrations are Pm=(Pm1,Pm2,...,Pml), thus the morphactin concentration calculating formulas of the stems and branches are described as follows:

$$P_{Mi} = \frac{f(x_0) - f(S_{Mi})}{\sum_{i=1}^{k}(f(x_0) - f(S_{Mi})) + \sum_{j=1}^{l}(f(x_0) - f(S_{mj}))} \quad (8)$$

$$P_{mj} = \frac{f(x_0) - f(S_{mi})}{\sum_{i=1}^{k}(f(x_0) - f(S_{Mi})) + \sum_{j=1}^{l}(f(x_0) - f(S_{mj}))} \quad (9)$$

In formula (8) and (9), x0 represents the initial original point, f (*) is a backlight function, the value of f (*) is in inverse proportion to sunlight condition. From above formulas, it is easy to conclude that the sum morphactin concentration of all the growing points in a plant is 1 (shown in Fig.1), namely:

$$\sum_{i=1}^{k}\sum_{j=1}^{l}(P_{Mi} + P_{mj}) = 1 \quad (10)$$

After morphactin concentrations are determined, there contains k + l growing points (x1, x2 ,..., xk + l) in stems and vines, according to (8) or (9) can calculate these points’ morphactin concentration respectively (p1, p2 ,..., pk + l). Then randomly generates a number which is within [0,1], this number is going to determine which point is the next growing point, it's just like throwing a ball in the [0,1] interval, the corresponding point of the state space that the ball falls into will be the next growing point (shown in Fig.1). The values of k and l are corresponding changed when new branches outgrows, by this time, the old growing point will be deleted from the outgrowth set, and the new growing point will be joined into the outgrowth set, repeat this step until there are no new branches outgrow, in such a way, it will grow up into a complete plant eventually.

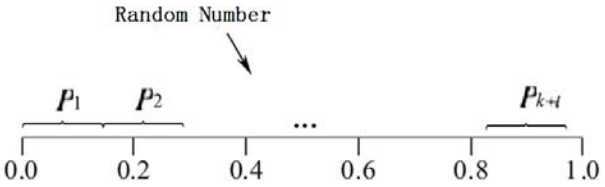


FIGURE 1. Pgsa for partner selection problem

3.2.1 Decision variables. Here, the decision variable of partner selection problem is designed as a vector $(f_1, f_2, ..., f_n)$. This setting approach is quite reasonable. The relationship between f_i and t_i is determined by u_{ij}, if the element value of u_{ij} is 0, it means that the candidate company is not selected; if the element value of u_{ij} is 1,it means that the candidate company is selected as a partner.

3.2.2 Termination. In order to improve computing efficiency and convergence rate, meanwhile ensure the calculation quality of the algorithm, the termination criterions of searching are designed as follows: (A) Because in PGSA searching optimal solution process, the searching scope is the entire growing space, if searching step length is 1, all of the optimal solution will be found, but when the growing space is larger, it will take longer time in searching. Therefore, it can be considered that set step length to a larger value at the beginning of the searching, if the optimal solution can not be found, then decreases step length to continue searching, and so forth this process, until the step minuses to 1. The initial step length value is generally set to 2n; (B) In the process of searching the optimal solution, in order to avoid the phenomenon that the optimal value has not been found but the searching process stops earlier, or the phenomenon that the optimal solution has already been found but the searching is still continued, here we proposes a solution method by setting the maximum number of loop iterations and the maximum number of repeated reconciliation. In the searching process of the optimal solution, if the current search iteration number has reached the setting maximum number of loop iterations, or the current obtained optimal solution recurring time reached the setting number of maximum number, then it will be considered that that the current obtained solution is the optimal solution, and the searching process stops.

The specific steps of partner selection problem based on PGSA are described as follows:

Step1: Using greedy method to generate starting point x0 (a group of candidate companies) randomly, this generation method is good for improving the quality of initial solution meanwhile ensure the generality of initial solution, making the initial value close to the optimal solution as far as possible. Initializing the optimal value variable Xmin=x0, and the optimal solution function Fmin=f(x0), setting the value of maximum number of loop iterations and the maximum number of repeating solutions;

Step2: Starting from x0, within the closed area xi, along the positive and negative direction of each axis, writing line segments which is parallel with the axis, searching the possible growing points in each line segment with step length. Choosing a prior growing point, starting from this node, if the searching growing point is not in growing space , or it does not meet the growing condition， then the node is deleted, if step >1,then step=step-1; otherwise, comparing the function values of growing point and starting point, if the former is greater than latter, then deletes the point, otherwise the point is added to the growing point set;

Step3: Maintain the current best solution of function, selecting the point from the growing set which has the maximum difference value with the base point, comparing function value of this point and Fmin, if the function value of new growing point is greater than Fmin, then maintains Fmin, Xmin; is invariable; if the function value of new growing point is equal to Fmin, then maintain this growing point, and put this point into the growing point set; if the function value of new growing point is less than Fmin,, then replaces the value of Fmin, as the function value of new growing point, replacing value of Xmin as suffix value of new growing point, deletes the original old growing point from growing point set, and grows new branches to 2n directions from the new growing point；

Step4: Judging whether satisfies the searching terminate conditions, if the cycle time reaches hypothesis maximum number of loop iterations, or the current obtained solution

has not changed for hypothesis maximum number of repeat time, then calculating the morphactin concentration value of each growing point in stems and branches according to formula (8) or (9); otherwise, withdraw the searching;

Step5: Establishing probability space within [0,1]: Pi+1=Pi+1+Pi; Pi=Pi/Pn;

Step6: Generating a random number within [0,1];

Step7: If the random number belongs to (Pi,Pi+1], then the corresponding point to this number will be the next new growing point;

Step8: If there is no new branches occur when repeating times of Xmin reaches the maximum repeating number or searching time reaches the maximum searching number, then growing process stops; otherwise, return to Step2;

Step9: Return values of Xmin and Fmin.

4. Examples. To validate the performance of our proposed algorithm, here, an example is introduced. Assuming a supply chain is formed by 5 tasks which contain Design (D), Procurement (P), Manufacture (M), Sale (S) and Logistics (L), the number of candidate companies for each task is 3,3,5,4 and 5, values of performance parameter $t_{e_{ij}}, c_{e_{ij}}, q_{e_{ij}}, r_{e_{ij}}$ of each candidate company for finishing a task is shown in Table.1, and values of link cost $d_{ij,vq}$ of each candidate is shown in Table.2. The weight values of object function are $W = (w_1, w_2, w_3, w_4, w_5) = (0.28, 0.30, 0.24, 0.16, 0.02)$. Here, the maximum loop iteration time sets to 200, maximum repetition time sets to 50, we use genetic algorithm (GA), particle swarm optimization algorithm (PSO), and PGSA to calculate the object function respectively. Experiment are all done in the circumstance of P4 CPU, RAM 1G, frequency 1.60GHz. By programming with Matlab7, and 10 times independent calculating experiments, the optimal solution obtained by PGSA is (1 2 5 1 3), that is, the best combination of supply chain alliance partners is D1, P2, M5, S1 and L3, the optimal solution comparisons among PGSA, GA and PSO is shown in Fig.2, and the 10 times function value calculated by PGSA is shown in Fig.3.

TABLE.1 Value of parameters

type	$t_{e_{ij}}$	$c_{e_{ij}}$	$q_{e_{ij}}$	$r_{e_{ij}}$
D1	7.1	93	0.45	0.28
D2	7.5	90	0.41	0.23
D3	6.9	96	0.38	0.25
P1	4.8	80	0.41	0.36
P2	4.3	83	0.46	0.41
P3	3.7	87	0.39	0.34
M1	5.3	59	0.37	0.47
M2	5.5	67	0.41	0.52
M3	4.5	63	0.35	0.45
M4	5.1	54	0.33	0.49
M5	4.9	60	0.39	0.43
S1	3.9	80	0.44	0.64
S2	3.5	84	0.35	0.57
S3	3.7	88	0.38	0.61
S4	4.3	79	0.39	0.53
L1	3.1	74	0.25	0.43
L2	3.9	77	0.28	0.49
L3	3.3	82	0.35	0.45
L4	3.7	79	0.31	0.41
L5	3.5	83	0.30	0.47

TABLE.2 Values of link costs

	P1	**P2**	**P3**		
D1	11	17	14		
D2	10	19	14		
D3	18	18	12		
	M1	**M2**	**M3**	**M4**	**M5**
P1	14	15	15	11	17
P2	11	11	15	12	17
P3	16	11	14	12	13
	S1	**S2**	**S3**	**S4**	
M1	12	12	11	16	
M2	18	15	17	16	
M3	11	18	19	12	
M4	17	19	15	14	
M5	13	11	12	13	
	L1	**L2**	**L3**	**L4**	**L5**
S1	13	14	11	11	13
S2	18	17	14	12	17
S3	17	19	13	11	19
S4	18	16	15	10	12

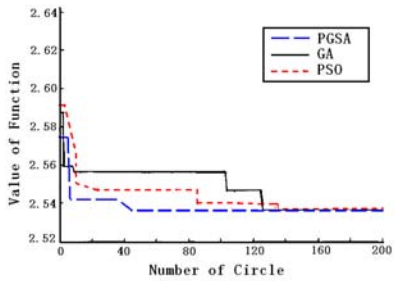


FIGURE.2 Comparisons among PGSA, GA and PSO

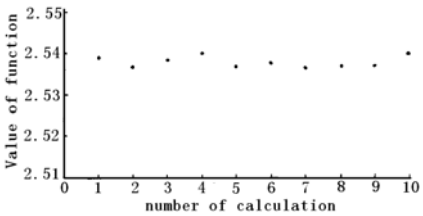


FIGURE.3 Value of function of 10 times experiment calculated by PGSA

As shown in Fig.2, we can see that PGSA has a better convergence rate than GA and PSO. as a matter of fact, with the number of candidate companies and tasks increasing, the calculating performance of PGSA will be shown even more clearly. From Fig.3 we can see that the 10 times results of function calculated by PGSA are all very close to the obtained optimal value, this shows that PGSA has a better stability.

5.Conclusions. According to the features of partner selection problem of supply chain, by considering the time, cost, performance and other factors, to establish a mathematical model of partner selection problem, on this basis, proposed a method that using a novel intelligent optimization algorithm-plant growth simulation algorithm to solve the model. The algorithm can search optimal solution rapidly within whole global scope, and it is easy to design and implement, it also has no more restrictions to the objective function and parameter settings, by calculating on real examples, the results verify better performance of this algorithm.

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