

## Resolve Supply Chain Procurement Conflict Based on Multi-Agent Adaptive Collaborative Negotiation

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### Abstract

To solve the procurement conflict between supplier and manufacturer, this paper proposes a collaborative planning model and an adaptive negotiation method by integrating intelligent multi-agent technology. First, a collaborative procurement, inventory and production planning model is built using the multi-level multi-item capacitated lot sizing problem method. Then the particle swarm optimization algorithm is combined with the simulated annealing algorithm to advance an adaptive negotiation method to solve the model taking the price and quantity of the raw materials as the negotiation items. The procurement conflict is resolved by achieving a mutually satisfactory agreement through the planning model and negotiation method. The simulation experiment shows the feasibility and effectiveness of the multi-agent adaptive collaborative negotiation method, which can reduce the total cost of supply chain and eliminate conflict. Compared with the genetic algorithm, the total cost reduction is larger, the local optimum is avoided, and negotiation times are decreased.

### Keywords

Supply Chain, Procurement Conflict, Multi-Agent, Collaborative Planning, Adaptive Negotiation.

### 1. Introduction

To adapt to the developing trend of fast response and low cost in the supply chain, purchasing is an important part of production, and operation and has transformed from a simple transaction to a strategic decision that considers the interests of the entire enterprise. Therefore, purchasing affects the profitability of the entire supply chain. However, because of the opposing goals among supply chain enterprises, conflicts concerning the price, quality, and other factors inevitably occur when a purchase is made. This leads to the supply chain being unable to quickly respond to the market demand, increasing the cost and decreasing the profit [1].

To solve the purchasing conflict in the supply chain, enterprises have begun to establish collaborative purchasing strategies, not only to support their internal operations but also to ensure effective external relations between supply and demand and to minimize the cost to the enterprise and supply chain [2]. Research concerning collaborative purchases in the supply chain primarily concentrates on the establishment of collaborative planning models and solution methods. In a just-in-time (JIT) model, research of the collaborative order-supply planning problem is for a single cycle [3]. Customer orders were researched to determine the optimal time for manufacturers to submit their parts orders to suppliers [4]. One study established an independent and distributed collaborative procurement planning model for each enterprise [5]. The LaGrange relaxation method was used to solve the collaborative conflict of purchase planning [6]. Another study combined the iterative process of a genetic algorithm and negotiation to form a type of global optimization collaborative planning method that features multi-point and probability searches [7]. Finally, collaborative production purchasing planning was solved using a knowledge evolution algorithm [8]. Existing research can improve the traditional purchasing model, but there are still some deficiencies, as research of coordinated procurement rarely concerns conflict, which causes a supply chain enterprise to be unable to improve its strategic adjustment ability effectively. As it is not often combined with

artificial intelligence technology, the problem of decentralized distribution of a supply chain enterprise cannot be solved without increasing the operations time and cost. As the negotiation method is infrequently used when solving a collaborative planning model, the conflict cannot effectively be resolved.

Negotiation is a communication method that eliminates a dispute between a seller and a buyer and achieves a mutually satisfying agreement. Meanwhile, the technology of a distributive agent with the characteristics of interaction, autonomy, and learning is no longer restricted by time and space [9]. Therefore, applying the negotiation method based on multi-agent to supply chain purchasing can resolve the conflict and the problem of enterprise scattering. Because the particle swarm optimization (PSO) algorithm has global optimum choice ability and is simple to implement [10] and the simulated annealing (SA) algorithm can avoid the PSO issue with local optimum [11,12], a negotiation method combining the two algorithms can provide an optimal decision for the enterprise. In this paper, to solve the conflict between the supplier and manufacturer concerning the price and quantity of raw material being purchased, coordination model and negotiation method based on multi-agent are posited. The collaborative planning model based on multiple periods, enterprises, products and raw materials can minimize the total cost of the supply chain. Through the negotiation method based on PSO and SA, mutually satisfactory results can be obtained.

## 2. Model building

### 2.1 Problem description

Two-stage supply chain purchasing between the manufacturer's agent and the supplier's agent (both productive enterprises) is the research object. The manufacturer's agent provides products to downstream enterprises and the supplier's agent provides the raw materials for these products to the manufacturer's agent. To reduce the total cost of the supply chain, the two parties, through the exchange of respective cost information, negotiate concerning the quantity ordering price and planning for the raw materials. Then, the manufacturer's agent adjusts the production planning and the supplier's agent adjusts the production planning of raw materials to implement purchasing collaboration for the supply chain.

Using the optimal total cost of the supply chain as the collaborative plan, the supplier's agent and the manufacturer's agent both use the classic multi-level multi-item capacitated lot sizing problem (MLCLSP) to establish a decision-making model [13]. The following assumptions are used: the price of the products provided has been identified, the inventory of raw materials required by the manufacturer's agent is zero, the inventory of the raw materials produced by the supplier's agent is sufficient, the transportation cost is ignored, the ordering lead time is zero, the supplier's agent and the manufacturer's agent share a total cost threshold, and the allocation of the cost savings obtained after the negotiation is not specifically discussed.

The collaborative planning process is designed as follows: First, based on the product demand, the manufacturer's agent performs initial planning concerning the production, inventory and quantity of raw materials and submits the planned raw materials order to the supplier's agent. Based on the planning, the supplier's agent performs planning concerning the production and inventory of the raw materials and submits its cost and ordering price to the manufacturer's agent [14,15]. The manufacturer's agent calculates its own cost and the total cost based on the decision-making model. If the total cost exceeds a given threshold, the manufacturer's agent will negotiate with the supplier concerning the order quantity and price for the raw materials based on the method designed in this paper. The negotiation is repeated until the total cost is less than the given threshold and the results of the production and inventory planning are achieved.

### 2.2 Collaborative procurement planning model

#### 2.2.1 Definition of the symbols and parameters

(1) Sets

T: The set of production times.

M: The set of manufacturer's agents.

S: The set of supplier's agents.

P: The set of products produced by M.

Q: The set of raw materials purchased from S by M to produce P.

J: The set of resources used by M to produce P.

K: The set of resources used by S to produce Q.

(2) Variables

t: A production time,  $t \in T$ .

m: A manufacturer's agent,  $m \in M$ .

s: A supplier's agent,  $s \in S$ .

p: A type of product produced by m,  $p \in P$ .

q: A type of raw material purchased from s by m to produce p,  $q \in Q$ .

j: A type of resource used by m to produce p,  $j \in J$ .

k: A type of resource used by s to produce q,  $k \in K$ .

$ba_{t,m,p}$ : The external demand quantity of p at time t for m.

$C_{t,m,p,j}$ : The quantity of j held by m to produce p at time t.

$C_{t,s,q,k}$ : The quantity of k held by s to produce q at time t.

(3) Constants

$C'$ : The total cost threshold of the supply chain.

$ic_{m,p}$ : The unit inventory cost for m to produce p.

$gC_{m,p}$ : The fixed production preparation cost for m to produce p.

$fc_{m,p}$ : The unit cost for m to produce p.

$oc_{m,p,j}$ : The excess unit cost of j for m to produce p.

$B_{m,p}$ : The quantity for m to produce p; a large constant.

$ra_{m,p,j}$ : The unit demand quantity of j for m to produce p.

$bom_{p,q}$ : Relationship of the bill of materials (BOM) between p and q.

$C'_m$ : The cost threshold of m.

$ic_{s,q}$ : The unit inventory cost for s to produce q.

$gC_{s,q}$ : The fixed production preparation cost for s to produce q.

$fc_{s,q}$ : The unit cost for s to produce q.

$oc_{s,q,k}$ : The excess unit cost of k for s to produce q.

$B_{s,q}$ : The quantity for s to produce q; a large constant.

$ra_{s,q,k}$ : The unit demand quantity of k for s to produce q.

$C'_s$ : The cost threshold of s.

(4) Decision variables

$y_{t,m}$ : Whether m produces at time t.

$ia_{t,m,p}$ : The inventory of p held by m at time t.

$fa_{t,m,p}$ : The quantity for m to produce p at time t.

$oa_{t,m,p,j}$  : The excess quantity of j for m to produce p at time t.

$bc_{m,s,q}$  : The unit price for m to purchase q from s.

$ba_{t,m,s,q}$  : The quantity for m to purchase q from s at time t.

$y_{t,s}$  : Whether s produces q at time t.

$ia_{t,s,q}$  : The inventory of q held by s at time t.

$fa_{t,s,q}$  : The quantity for s to produce q at time t.

$oa_{t,s,q,k}$  : The excess quantity of k used for s to produce q at time t.

### 2.2.2 Collaborative planning model

(1) Model 1. The planning model for m is as follows:

$$MIN C_m = \sum_{t \in T} \sum_{m \in M} (\sum_{s \in S} \sum_{q \in Q} (ba_{t,m,s,q} * bc_{m,s,q}) + \sum_{p \in P} (ia_{t,m,p} * ic_{m,p} + gc_{m,p} * y_t + fa_{t,m,p} * fc_{m,p} + \sum_{j \in J} (oa_{t,m,p,j} * oc_{m,p,j}))) \tag{1}$$

$$s.t. \quad ia_{t-1,m,p} + fa_{t,m,p} = ba_{t,m,p} + ia_{t,m,p} \tag{2}$$

$$fa_{t,m,p} \leq B_{m,p} * y_t \tag{3}$$

$$ra_{t,m,p,j} * fa_{t,m,p} \leq C_{t,m,p,j} + oa_{t,m,p,j} \tag{4}$$

$$ia_{t,m,p}, fa_{t,m,p}, oa_{t,m,p,j}, ba_{t,m,p} \geq 0 \tag{5}$$

$$\sum_{t \in T} \sum_{m \in M} \sum_{s \in S} ba_{t,m,s,q} = \sum_{t \in T} \sum_{m \in M} bom_{p,q} * fa_{t,m,p}, \quad p \in P, q \in Q \tag{6}$$

$$y_{t,m} \in \{0,1\} \tag{7}$$

Eq. 1 indicates the decision objective function for the planning of m, including the cost of procuring raw materials, inventory of products, production preparation, production and capacity expansion of production. Eq. 2 indicates the balanced relationships among production, inventory and external demand. Eq. 3 indicates that the products will be subject to volume. Eq. 4 indicates the production capacity constraints. Eq. 5 indicates the non-negative constraints of the main decision variables. Eq. 6 indicates the BOM relationships among produced products and required raw materials. Eq. 7 indicates whether to produce or not, where 1 and 0 indicate producing and not producing, respectively.

(2) Model 2. The planning model for s is as follows:

$$MIN C_s = \sum_{t \in T} \sum_{s \in S} \sum_{q \in Q} (ia_{t,s,q} * ic_{s,q} + y_t * gc_{s,q} + fa_{t,s,q} * fc_{s,q} + \sum_{k \in K} (oa_{t,s,q,k} * oc_{s,q,k})) \tag{8}$$

$$s.t. \quad ia_{t-1,s,q} + fa_{t,s,q} = \sum_{m \in M} ba_{t,m,s,q} + ia_{t,s,q} \tag{9}$$

$$fa_{t,s,q} \leq B_{s,q} * y_t \tag{10}$$

$$ra_{t,s,q,k} * fa_{t,s,q} \leq C_{t,s,q,k} + oa_{t,s,q,k} \tag{11}$$

$$ia_{t,s,q}, fa_{t,s,q}, oa_{t,s,q,k}, ba_{t,m,s,q} \geq 0 \tag{12}$$

$$y_{t,s} \in \{0,1\} \tag{13}$$

Eq. 8 indicates the decision objective function for the planning of s, including the cost of the inventory, production preparation, production and capacity expansion of production. Eq. 9 indicates the balanced relationships among the production of raw materials, inventory and manufacturing demand. Eq. 10 indicates that the raw materials will be subject to volume. Eq. 11 indicates the production capacity constraints. Eq. 12 indicates the non-negative constraints of the main decision variables. Eq. 13 indicates produce raw materials whether or not, where 1 and 0 indicate producing and not producing, respectively.

(3) Model 3. The collaborative planning model for the supply chain is as follows:

$$MIN C = MIN C_m + MIN C_s \tag{14}$$

Eq. 14 represents the entire decision objective function of the supply chain. This paper uses the negotiation method to solve the collaborative planning model. m and s negotiate on the ordering quantity and price of raw materials, independently solve the planning model, and communicate the results of Eqs. 1 and 8. Both parties reduce the entire cost of the supply chain as a constrained object. If the result of Eq. 14 is greater than  $C'$ , repeat negotiation until the optimal cost to realize the collaborative procurement for the supply chain is reached.

### 3. Negotiation method

In this paper, we propose a negotiation method to achieve collaborative procurement planning for a supply chain. The method combines the PSO and SA algorithms and uses the price and quantity of the raw materials as the input [16]. The following sections discuss the analysis and design parameters and process of the two algorithms, and provide the entire supply chain collaborative negotiation process.

#### 3.1 Parametric settings for PSO

PSO randomly initializes a set of solutions as a particle, and the particle iteratively searches for the optimal particle in the solution space to obtain the optimal solution [17]. Assume that the manufacturer’s agent and the supplier’s agent each have a D dimension searching vector space that indicates the parameters of the planning model. Additionally, they each have a particle swarm whose size is N, and each particle can display the value of the decision variables. Use the results obtained by using the particles’ values in Eqs. 1 and 8 as the fitness. Judge the merit of the particles based on the relationship between fitness and  $C'_m$  or  $C'_s$ . The algorithm implementation process is the particle  $i$  ( $i = 1, 2, \dots, N$ ), which is constantly searching for the optimal value in the space. Its searching process is expressed in Eqs. 15 and 16.

$$\omega v_i^{l-1} + C_1 R_1 (P_i^{l-1} - x_i^{l-1}) + C_2 R_2 (P^l - x_i^{l-1}) \rightarrow v_i^l \tag{15}$$

$$x_i^{l-1} + v_i^l \rightarrow x_i^l \tag{16}$$

$l$  ( $l = 0, 1, 2, \dots, L$ ) indicates the evolutionary generations.  $v_i^l$  is a D-dimensional vector that indicates the speed of particle  $i$ ’s position change to constantly search in the space.  $x_i^l$  is also a dimensional vector that indicates the current position of particle  $i$ , and the location indicates the planning model’s solution.  $\omega$  is the inertia weight that adjusts the global and local searching ability of the particle swarm. Combined with the supply chain collaborative planning problem to determine the overall optimal supply chain cost, the particles must be able to search for the global optimal value. A value in [0.4, 0.9] indicates the algorithm performs well.  $R_1$  and  $R_2$  are random numbers in [0,1].  $P_i^l$  indicates the optimal location in which particle  $i$  is currently searching, as shown in Eq. 17.  $P^l$  indicates the optimal position in which the particle swarm is currently searching, as shown in Eq. 18.  $C_1$  and  $C_2$  are adaptive learning factors to accurately adjust the ability of particle  $i$  to reach  $P_i$  and  $P_g$ , as shown in Eq. 19.

$$P_i^l = \begin{cases} x_i^l, & \text{if } f_i^l < f_i^{l-1} \\ P_i^{l-1}, & \text{otherwise} \end{cases} \tag{17}$$

$$P^l = P_i^l, \text{ if } f_i^l = \min(f_1^l, f_2^l, \dots, f_i^l) \tag{18}$$

$$\begin{cases} C_1 = 4 * \frac{|f_i^l - f^l|}{f_i^l} \\ C_2 = 4 - C_1 \end{cases} \tag{19}$$

Among them,  $f_i^l$ ,  $f^l$  indicate the fitness of the optimal position  $P_i^l$  of the particle and the optimal position  $P^l$  of the particle swarm, respectively.

### 3.2 Parametric settings for SA

Because it is easy for PSO to be caught in the local optimum, it has lower precision in convergence and searching. SA first determines an initial temperature and a random solution. Under a given cooling speed, a new objective function value is obtained along with the continuous cooling that perturbs the initial solution. Accept the worst solution with its probability and accept a better solution with a probability of 1 until the lowest temperature is reached [18]. To avoid PSO causing the supply chain collaborative planning process to be caught in a local optimum, design the SA algorithm steps and parameters as follows:

- (1) Set the following parameters: the initial temperature  $T_0$ , cooling speed  $a$  ( $0 < a < 1$ ), ending temperature  $T'$ , initial solution  $x_i$  (D dimensional vector), and fitness  $f_i$ .
- (2) If  $T_0 > T'$ , go to (3); otherwise, stop the algorithm and output  $x_i$  and  $f_i$ .
- (3) Given a random disturbance, a new feasible solution  $x'_i$  is generated in the D-dimensional vector space. Calculate the fitness  $f'_i$  and the difference value  $\Delta f$  between  $f'_i$  and  $f_i$ .
- (4) Accept  $x'$  if it meets  $\min\{\exp(-\Delta f / T_0), 1\} > rand(0,1)$  and go to (5). Otherwise, go to (3).
- (5) Set  $x_i = x'_i, T_0 = aT_0$  and go to (2).

### 3.3 Implementation steps for collaborative procurement based on negotiation

To ensure the supplier's and manufacturer's agents are both satisfied with the supply chain procurement planning, apply a mixed negotiation method by merging the PSO and SA with the supply chain collaborative procurement. Automatically adjust the optimization direction of the solution by the adaptive learning factor in PSO and the adaptive acceptance probability in SA, and obtain the optimization solution of the model. Combining the model and negotiation methods, the entire collaborative procurement procedure is as follows:

Step 1. An agent receives the quantity and price of raw material and cost information from the other agent and then begins the evaluation, calculating  $C_m$  or  $C_s$  based on models 1 or 2 or C based on model 3.

Step 2. If  $C \geq C'$ , randomly generate N particles with a D-dimensional vector. Initialize the decision variable values of models 1 and 2 and the values of  $bc_{m,s,q}$  and  $ba_{t,m,s,q}$  that are an invariable quantity and price; then, obtain  $x_i^l$ . Combine the variables to calculate the fitness  $f_i^l$  of the particle with other constants; then, initialize the speed of  $v_i^l$  and  $P_i^l$  and go to Step 3. Otherwise, accept the proposed adverse negotiation results and output the decision variables and total cost.

Step 3. Use  $P^l$  obtained from Eq. 18 in Eqs. 1 or 8 to obtain the fitness  $f^l$ . If  $f^l < C'_m$  or  $f^l < C'_s$ , go to Step 4. Otherwise, go to Step 6.

Step 4. Initialize  $T_0$ ,  $a$ , and  $T'$ . If  $T_0 > T'$ , go to Step 5. Otherwise, submit the quantity and price of raw material and cost (fitness  $f^l$ ) included in  $P^l$  to the other agent and go to Step 1.

Step 5. Given a random disturbance, a new particle  $\hat{x}_i^l$  is generated. Calculate the fitness  $\hat{f}_i^l$ , accept  $\hat{x}_i^l$  if it meets  $\min\left\{\exp\left(-\left(\frac{\hat{f}_i^l - f_i^l}{T_0}\right), 1\right)\right\} > rand(0,1)$  and then,  $x_i^l = \hat{x}_i^l, T_0 = aT_0$ .

Step 6. Calculate  $C_1$  and  $C_2$  according to Eq. 19 and establish the value of  $\omega$ . Generate the new feasible solution of  $x_i^l$  by adjusting the particles according to Eqs. 15 and 16. Calculate  $f_i^l$  and obtain  $P_i^l$  based on Eq. 17 and go to Step 3.

### 4. Simulation experiment

#### 4.1 Example design

This study establishes a simulation example to prove the effectiveness of the model and method. The structure of a two-level supply chain is shown in Fig. 1. There are two supplier’s agents and three manufacturer’s agents. The arrows indicate the relationship of demand and supply between upstream and downstream. The variables and model in section 1.2 are used to establish the model for the supply chain collaborative procurement problem. The optimal planning function of the manufacturer’s agent is model 1, the supplier’s agent is model 2, and the collaborative planning of entire supply chain is model 3.

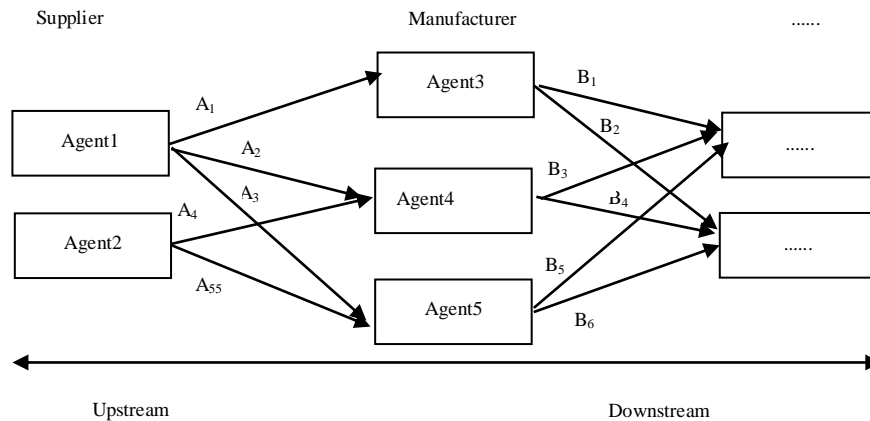


Fig. 1. Two-level supply chain structure for multiple enterprises, products and raw materials  
 Values are assigned for the collection, variables and constants of models 1, 2 and 3. As there are several parameters, use Agent 3 as an example to explain the specific assignment method. The assignment of other agents is not expanded. Set  $C' = 12000$  and  $C'_3 = 8100$ .

- (1) Arrange four production periods for each time, namely,  $T = \{1, 2, 3, 4\}$ .
- (2) There are two suppliers, Agent 1 and Agent 2, namely,  $S = \{1, 2\}$ .
- (3) Production requires three types of raw materials, A1, A2 and A3, namely,  $Q = \{1, 2, 3\}$ .
- (4) Production requires two types of products, B1 and B2, namely,  $P = \{1, 2\}$ .
- (5) Production requires two types of resources to produce B1 and B2, namely,  $J = \{1, 2\}$ .
- (6) External demands are shown in Table 1.

Table 1. External demand assignment for Agent 3

$t$	1	2	3	4
$ba_{t,3,1}$	55	45	65	70
$ba_{t,3,2}$	35	40	35	45

- (7) Resource ownership is shown in Table 2.

Table 2. Resource ownership assignment for Agent 3

$t$	1	2	3	4
$C_{t,3,1,1}$	95	80	105	100
$C_{t,3,2,2}$	135	120	140	125

- (8) Constant assignment is shown in Table 3.

Table 3. Constant assignment for Agent 3

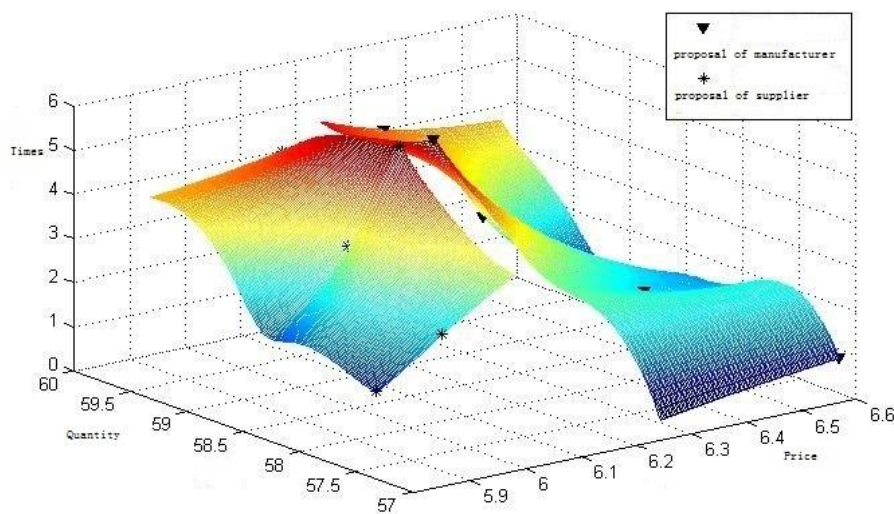
product	$ic_{3,p}$	$gc_{3,p}$	$fc_{3,p}$	$oc_{3,p,j}$	$B_{3,p}$	$ra_{3,p,j}$	$bom_{p,q}$
1	3	30	3	2	550	2	2
2	4	35	3	3	600	1	1

**4.2 Simulation analysis**

Use the collaborative negotiation process between supplier’s Agent 1 and manufacturer’s Agent 3 as an example to analyze the result.

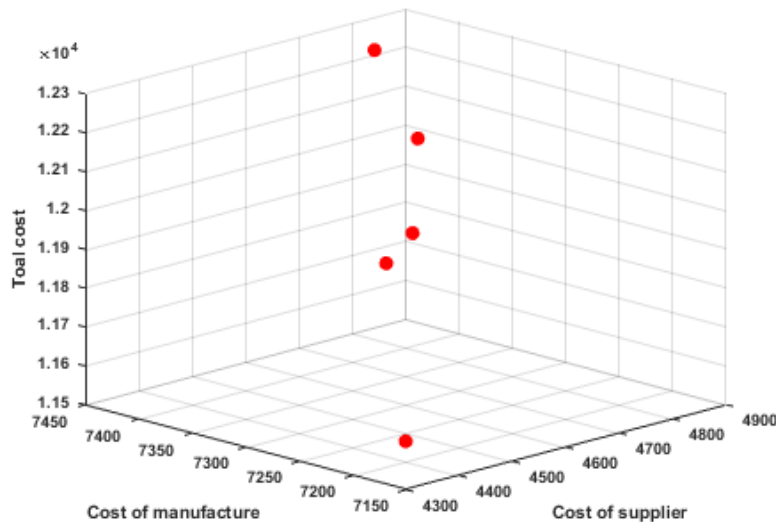
First, consider the scenario with no collaboration. When the demand quantity and prices of all products and raw materials are determined, the total cost of the supply chain can be determined. Then, successively solve other parameters based on the relationship between the supplier’s agent and the manufacturer’s agent. Determine the cost for each agent by referring to models 1 and 2, and finally, obtain the total cost of the supply chain (12,246 based on model 3).

Then, use the MATLAB software program to simulate the collaborative purchasing planning model of the supply chain based on the negotiation method, using the values  $N=20$ ,  $L=100$ ,  $\omega=0.5$ ,  $T_0=1000000$ , and  $a=0.8$ ; the output is shown in Fig. 2. Fig. 2(a) shows the negotiation process and resulting price and quantity of raw materials. The optimal solution (6.245, 59) was obtained after negotiating 5 times, and achieved a satisfactory result for both parties. Fig. 2(b) shows the changing trend of the costs for Agent 1 and Agent 3 and the total cost, which was 11,567.7. Although the costs fluctuate, compared with a purchase with no collaboration, the total cost decreased by 5.5%. The result indicates that the model and method can eliminate procurement conflicts between a supplier and manufacturer and reduce the total cost of the supply chain.



(a) Negotiation process and result

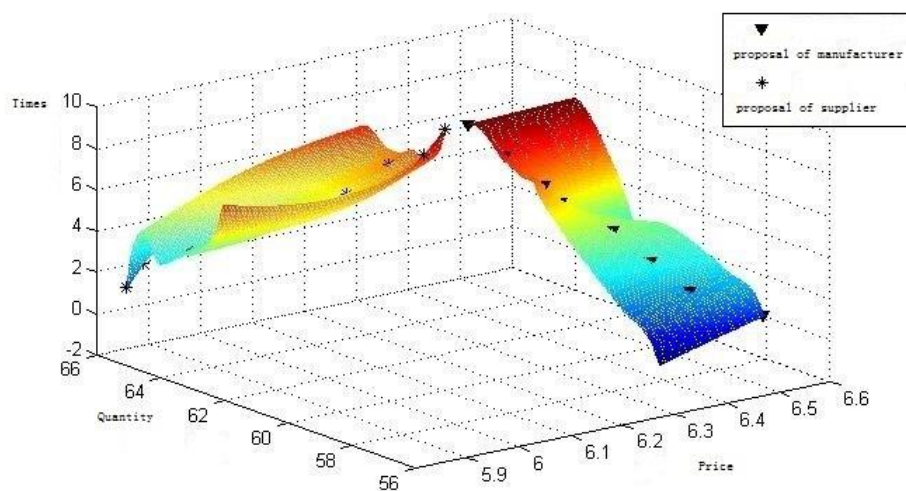




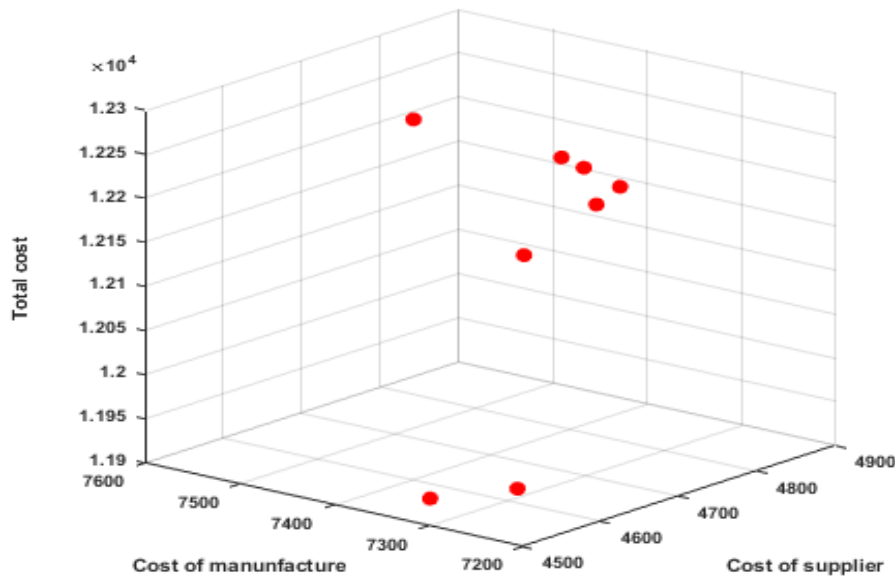
(b) Cost changing trend

Fig. 2 Simulation output results using the proposed model and negotiation method

The genetic algorithm (GA) is similar with PSO and SA but is also a type of probabilistic adaptive global optimized algorithm, primarily used in the early negotiation process [19,20]. To validate the effectiveness of the proposed negotiation algorithm in this planning model, GA is used to solve the model. Although improved versions of GA exist, this study cannot determine the optimal algorithm to use for comparison as the variations are complicated. Therefore, this study uses the basic GA simulation method to achieve the collaborative procurement planning model for a supply chain. Establish the population size at 20, the selection probability at 0.5, the crossover probability at 0.8, the mutation probability at 0.05, and the evolution algebra at 100. The output is shown in Fig. 3, which is in the same format as Fig. 2. Fig. 3(a) shows that the optimal solution (6.285, 63) was obtained after negotiating 8 times and Fig. 3(b) shows the final total cost of 11,910.5, which, when compared with procurement with no collaboration, has decreased by 2.7%. This indicates that although GA can also decrease the total cost, it is easy to be caught in a local optimum and the negotiation time increases, so it is less effective than the adaptive negotiation method proposed in this paper.



(a) Negotiation process and result



(b) Cost changing trend

Fig. 3 Simulation output results based on genetic algorithm

## 5. Conclusion

Resolving purchasing conflicts between enterprises is important to guarantee low cost and high efficiency in supply chain operations. A collaborative procurement strategy is an effective method to resolve conflicts, and negotiation based on multi-agents is a core method of the optimized synergy effect. In this paper, while considering the procurement conflict between supplier and manufacturer, a secondary supply chain constructs an MLCLSP collaborative planning model and posits a negotiation method based on the fusion of the PSO and SA algorithms to solve the model. Unlike the previous collaborative planning models and negotiation methods, this model focuses on the conflicts of raw materials' purchasing price and quantity to embody the importance of enterprise purchasing through negotiation methods designed with an adaptive learning factor and adaptive accepting probability to avoid the local optimum and improve the intelligence and adaptability. The experimental results show that compared with non-collaboration, the use of the model and method can achieve satisfactory results for both parties and reduce total cost. Compared with the genetic algorithm, the negotiation method increases the cost reduction and reduces the negotiation times.

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