Research on Negotiation of Manufacturing Enterprise Supply Chain Based on Multi-agent

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Abstract

In the multi-agent system of manufacturing enterprise supply chain, each node enterprise has different demands on the price, quality, cost, delivery time, quantity, response time, service conditions and other factors, that will cause lots of conflicts between supply chain partners, and negotiation is the basic means to solve these conflicts. In this paper, a multi-objective negotiation model will be presented, and then negotiating tactics and steps between purchasing agent and supplier agent will be discussed. Next, an example is discussed and simulated by computer technology for validating the negotiating model. It is helpful to save negotiation time and improve negotiation efficiency, and optimize the manufacturing enterprise supply chain management. Based on this, manufacturing enterprise can maximize the benefits and improve the operational efficiency of supply chain.

Keywords: Negotiating model, Multi-objective, Negotiating tactics, Supply chain management

1 Introduction

As an inevitable development result of artificial intelligence, modern computer and communication technology, agent and multi-agent have attracted great attention and concern in the academic and industrial fields, and are commonly used in various fields [1-2]. In the multi-agent system of manufacturing enterprise supply chain, each node enterprise is independent, the goal of each node enterprise is to maximize profits, and different cooperation strategies and trading mode will be adopted by each node enterprise based on interests, operation mode and product features [3-7]. Therefore, each enterprise has different requirements on product price, quality, cost, delivery, quantity, response time, service conditions and other factors. All of these demands will produce a large number of conflicts between the manufacturing enterprise and cooperative partner. Negotiation is the basic means to resolve these conflicts and is the main form of interaction between supply chain partners. Cooperative enterprise can realize bilateral or multi joint tactics by means of negotiation in the manufacturing enterprise [8-11]. The application of multi-agent technology to manufacturing enterprise supply chain negotiation, will be helpful to realize the coordination and control between enterprises in manufacturing enterprise, to promote efficient, flexible and efficient cooperation among enterprises, to save negotiation time and improve negotiation efficiency, to improve the operation efficiency of manufacturing enterprise supply chain.

In this paper, we mainly discuss the multi-objective negotiation mechanism of manufacturing enterprise supply chain based on multi-agent. At first, main problems will be put forward after our analysis of relevant literature. Then, the negotiation model is constructed and the negotiation process is analyzed. Finally, the negotiation model is simulated by computer technology.

2 Literature Review

There are many researches about the agent and multi-agent as well as the negotiation between them. Stam Franklin thought the agent is a system that perceives the environment and acts on the environment to achieve its plan [12]. Wooldridge thought the agent was a computer system designed to achieve the goal of pure packaged in the environments, can perform flexible behavior [13]. Shoham thought the agent was an entity with the mental state of beliefs, capabilities and commitments [14]. Lane considered the agent is a computing unit with control problem solving mechanism, which can be known as a solver, a module or an expert system [15]. In solving complex problems, the ability of a sole agent is limited, so, lots of mutually independent agents can be formed a multi-agent system by coordinating their behavior. In the multi-agent system, the agents will coordinate their goals, accomplish some specific tasks or achieve some goals by collaboration, and share knowledge about solving problems and solving methods [16-17].

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If the negotiation is to carry on under the complete information, the agent involving the negotiation will fully understand each other's information. It is easy to reach the Nash equilibrium, communication and negotiation time between negotiating agents will be reduced greatly. In fact, more negotiations are non-cooperation based on incomplete information, such as multi-objective negotiation. Both parties are involved in the negotiation for multiple target negotiation, after several rounds negotiation maybe achieve the possible solutions. Durfee and Lesser think, negotiation is the exchange of structured information between the parties to form a plan. Conflict is the starting point of the negotiation, through a series of mutual concessions, and consensus in the end, the negotiation is a process of bilateral or multi joint decision-making and mutual compromise [18]. In the multi-agent system of manufacturing enterprise supply chain, each agent representing the enterprise is to communicate with each other through the network, and interact with each other until the goal is reached [19-20]. Sycara focused on the study of justice, is to use the negotiation model, analyze and improve negotiation strategies, choose the right way to negotiate, arrange a reasonable agenda for the negotiations, and maximize the interests of both parties [21]. Neumann divided the negotiations into sole objective and multi-objective. Sole objective negotiation refers to the two sides to negotiate a goal. The goal is to achieve a consensus on negotiated success. Multi-objective negotiation means that the two sides will interact with each other. All the goals can be reached when the agreement is reached. In the supply chain negotiation, it is necessary to negotiate with a number of negotiating objectives, such as price, quality, delivery time, supply quotas, etc. [22]. Faratin studied from the perspective of negotiation tactics, thought negotiation can be divided into time dependent, resource dependent and dependent behavior, the factors that affecting the negotiation process of convergence mainly includes time, resources and behavior, and deliberative bodies can produced a variety of negotiation tactics, provided the calculating function of the negotiation fuzzy value, and checked the validity of the calculating function by empirical data [23].

About the sole objective negotiation, Fatima et al. studied negotiation between two parties of negotiation on price and utility based on Web. And built a negotiation model and proposed the negotiation strategies of two fair prices based on multi-agent system [24-25]. Jennings et al. have discussed the negotiation model and tactics between both negotiating parties based on the multi-agent [26]. Sierra et al. provided the calculating function of the negotiation fuzzy value, and verified the validity of the calculating function by empirical data [23]. Valverde *et al.* mainly studied computing method of negotiation fuzzy value [27]. Srinivas Talluri proposed a buyer–seller game model, this model effectively evaluates alternative bids based on the ideal targets set by the buyer [28]. Joe Zhu and Xiaobing Zhang developed a new buyer-seller game model which the efficiency is maximized with respect to multiple targets set by the buyer. The model allows the buyer to evaluate and select the vendors in the context of best-practice [29-30]. Wan and Far presented an agent negotiation protocol that facilitates the solving of group-choice decision making problems [31]. Wang and Tadisina described a case study and built the simulation system based on a theoretical model and a real world case [32]. Li et al. created and described an Internet-based multi-agent prototype system to explore how the process of marketing tactics can be improved by an internet-enabled multi-agent intelligent system [33]. Kwon et al. implemented MACE-SCM developed a framework based on multi-agent and case-based reasoning to facilitate collaboration and information sharing in the presence of high supply and demand uncertainties [34]. Gao et al. focused on multi-stage model for the cooperation of the virtual enterprise and the self-study negotiation model based on Bias distribution, the problem of task allocation and conflict resolution in virtual enterprise is solved by the agent, and the validity of the model is proved by experiments [35-36]. Carrascosa et al. presented a flexible and efficient integration of high-level [37]. Lin et al. studied the multi-agent negotiation mechanism to enhance the existing methods, and then evaluates the integrated systems performance through experimentation on the order fulfillment process in the context of Chinese metal industry [38]. Suh and Wen established the linkage between non-cooperative bargaining solutions [39].

About the multi-objective negotiation, Kraus proposed a general multi-agent negotiation framework model, which is a formal definition of negotiation tactics, negotiation goal and negotiation process, and the sociality and cooperation of multi-agent negotiation are discussed [40]. Park and Yang proposed a multi-objective negotiation model for e-commerce environment, and discussed the method for making the negotiation agent to achieve the satisfactory solution or the optimal solution [41]. Huang et al. presented a multi-agent negotiation approach for parallel machine scheduling with multi-objectives in an electro-etching process [42]. Huang and Liao presented a 4-phase negotiation model for B2C e-commerce which includes information collection, search, negotiation, and evaluation [43]. Jiao et al. developed an agent-based collaborative multi-contract negotiation system based on the manufacturing paradigm to support multiple echelon negotiations [44]. Lia and Sheng discussed the multi-agent model for the reasoning of uncertainty information [45]. Jorge et al. discussed supply chains collaborative planning by a negotiation-based mechanism and multi-agent system [46]. Wang and Chen proposed a multi-objective negotiation model based on multi-agent, and put forward a general multi-agent negotiation protocol based on Q-study and Bayes learning machine [47]. Shi et al. proposed the multi-agent negotiation model applied in multi-objective optimization. The model is applied in evolutionary multi-objective optimization to realize its parallel and distributed computation [48]. Fei and Chen proposed an integrated multi-agent, multi-object and multi-attribute intelligent negotiation model. In the model the idea of simulated annealing iterative algorithm is introduced, and deliberated SA algorithm adjusts dynamically the correlativity to obtain the optimized negotiation solution [49]. Wu et al. proposed an evolving network models with physical position neighborhood connectivity and studied the clustering coefficients [50]. Chen et al. proposed a Buyer Collective Purchasing model applied in a multi-agent framework [51]. Lee et al. proposed a procurement system across other disciplines and retrieved information with relevant parties so as to get a better co-ordination between supply and demand sides [52].

In this paper, manufacturing enterprise supply chain multi-agent system will be took as the research object, the multi-agent negotiation mechanism will be took as the core, the multi-objective negotiation model of manufacturing enterprise supply chain based on multi-agent will be built based on the related theory, the multi-objective negotiation mechanism between the core enterprise of manufacturing enterprise supply chain and suppliers will be discussed, and the actual calculation example is to verify the negotiation model. That will be useful for clearly understanding and learning the multi-objective negotiation essence of manufacturing enterprise supply chain based on multi-agent, to improve the operational efficiency of manufacturing enterprise supply chain.

3 Negotiation Model and Tactics

3.1 Negotiation Hypothesis

In the negotiation process, Parties to the consultations need communicate in order to complete the negotiation at a certain time. And this communication is based on a comprehensive negotiated agreement, the negotiation tactics is a target or multiple targets on the basis of the offer (price) or offer combination (price, quality, delivery, delivery quotas, etc.), that is helpful to improve the efficiency of conflict resolution and resource allocation by means of a multi-step decision. In order to solve the different problems of negotiation, it is necessary to make hypothesis about the different agents involved in the negotiation

(1) Agents are rational, are striving to maximize their own interests, will not accept less than their deserving benefits solution. Let (u_s , u_c) as the final negotiation results, so $u_s \geq c_s$, $u_c \geq c_c$. c_s and c_c is the conflict point of the two sides.

(2) Agent is a rational individual, which each individual involved in negotiation is negotiated by the rules of doing things, and then all agents have individual rationality.

(3) Agent also has joint rational, that is to say when there is a negotiation outcome N_p enabling participants to gain greater utility, negotiating participants would not choose another result N_Q as the final results of the consultation.

(4) Negotiation among agents is carried out under incomplete information. For example, they do not even know each other's bidding tactics and risk preferences, etc..

(5) No fraud in negotiation, negotiating participants have sincerity in the negotiation process.

(6) Negotiating agent owns certain environmental awareness.

(7) In the process of offer and counter-offer, the bid of supplier agent is higher than the bid of manufacturing enterprise purchase agent. Suppliers agent is $G\left(x^i\right) \geq G\left(y^{i-1}\right)$ and purchasing agent is $N\left(y^i\right) \leq N\left(x^{i-1}\right)$, eventually the price of two sides is tending to agreement. Where G and N represent the utility functions of suppliers and buyer, x and y represent the offer combinations of suppliers and buyer.

(8) There are two suppliers in the negotiation process, if $N(X^7) = w_g^p N_p(X_p^7) + w_g^Q N_Q(X_Q^7) = 0.6 \times 0.5 + 0.4 \times 0.5 = 0.5$ $G\left(Y^7\right) = w_n^p G_p\left(Y_p^7\right) + w_n^Q G_Q\left(Y_Q^7\right) = 0.6 \times 0.5 + 0.4 \times 0.5 = 0.5$, the two suppliers will invole negotiation, the willingness of participating in negotiation is $X^1 = \left(X_p^1, X_Q^1\right) = \left(400, 100\%\right)$.

(9) The negotiation process between purchasing agent and supplier agent in manufacturing enterprise supply chain is the offer and counter-offer, the offer of purchasing agent is less than the offer of supplier agent, but the eventual offer will tend to agree.

Here, rationality means that behavior of negotiating participants should be taken to improve the individual interests, and does not refer to the actual action taken.

3.2 Negotiation Model and Tactics

Multi-objective negotiation of manufacturing enterprise supply chain based on multi-agent is the negotiation between the core enterprise and supplier, that is between purchasing agent and supplier agent. In the manufacturing enterprise supply chain, the main participants will negotiate about price, quality, delivery and supply quotas. At this time, the price is no longer the dominant position. The research significance of the delivery date is not important. The delivery date is ahead of time, and it will increase the cost of inventory for the core enterprises, delivery delay will cause shortages, so that the interests of enterprises are damaged. Therefore, the delivery date as far as possible is just in time. In this paper, the negotiation of delivery time is not studied further. The suppliers and core enterprise among the manufacturing enterprises supply chain will share the benefits. From the long-term strategic partnership, supply quotas are generally fixed or change range is very small, so the supply quota is not the focus of this paper. The focus of this paper is to conduct in-depth research on price and quality negotiation.

In the multi-agent system of manufacturing enterprise supply chain, there is a situation which an agent negotiates with a number of agents. For example, the core enterprise of manufacturing enterprise supply chain will negotiate with suppliers agent about price and quality on some parts or raw materials. Their negotiation process is depicted in Figure 1.

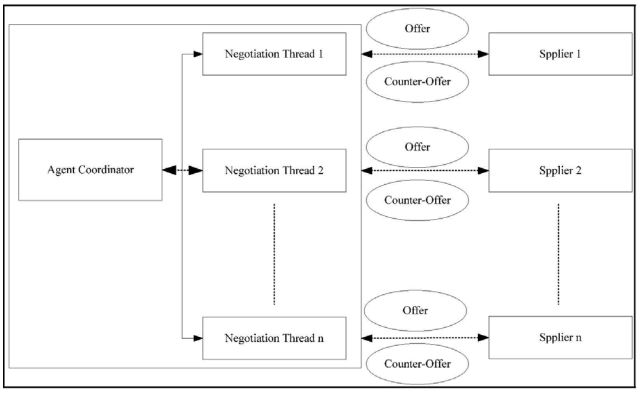


Figure 1. Negotiation process of one to many of manufacturing enterprise based on multi-agent

At time $t = t_i$, the offer combination of the purchasing agent is: $X^i = \left(X_p^i, X_Q^i\right)$. In the formula, X_p^i represents price, X_Q^i represents quality, $i = 1, 2 \cdots, n$.

At time $t = t_i$, the offer combination of supplier agent is: $Y^i = \left(Y_p^i, Y_Q^i\right)$. In the formula, Y_p^i represents price, Y_Q^i represents quality, $i = 1, 2 \cdots, n$.

When $i = 1$, X^1 and Y^1 represent the initial offer of purchasing agent and supplier agent respectively.

N_p and N_Q respectively represent the utility function of price and quality in offer combination of purchasing agent. G_p and G_Q respectively represent the utility function of price and quality in offer combination of supplier agent. The ranges of N and G is [0,1].

w_g^p and w_g^Q respectively represent the important degree of price and quality in offer combination of supplier agent. w_n^p and w_n^Q respectively represent the important degree of price and quality in offer combination of purchasing agent. The relation of them is as following.

$$\begin{cases} w_g^p + w_g^Q = 1 \\ w_n^p + w_n^Q = 1 \end{cases} \quad \textbf{(1)}$$

The utility function of price and quality of purchasing agent are as following.

The price utility function of purchasing agent:

$$N_p^i\left(X_p^i\right) = \frac{-1}{\left(Y_p^1 - X_p^1\right)} \times \left(X_p^i - Y_p^1\right) \quad \textbf{(2)}$$

The quality utility function of purchasing agent:

$$N_Q^i\left(X_Q^i\right) = \frac{1}{\left(X_Q^1 - Y_Q^1\right)} \times \left(X_Q^i - Y_Q^1\right) \quad \textbf{(3)}$$

The utility function of offer combination of purchasing agent:

$$N\left(X^i\right) = w_g^p N_p\left(X_p^i\right) + w_g^Q N_Q\left(X_Q^i\right) \quad \textbf{(4)}$$

Similarly, the related utility function of supplier agent are as following.

The price utility function of supplier agent:

$$G_p^i\left(Y_p^i\right) = \frac{1}{\left(Y_P^1 - X_P^1\right)} \times \left(Y_P^i - X_P^1\right) \quad \textbf{(5)}$$

The quality utility function of supplier agent:

$$G_Q^i\left(Y_Q^i\right) = \frac{-1}{\left(X_Q^1 - Y_Q^1\right)} \times \left(Y_Q^i - X_Q^1\right) \quad \textbf{(6)}$$

The utility function of offer combination of supplier agent:

$$G\left(Y^i\right) = w_n^p G_p\left(Y_p^i\right) + w_n^Q G_Q\left(Y_Q^i\right) \quad \textbf{(7)}$$

The offer tactics of the two sides in manufacturing enterprise supply chain are as following.

The offer tactics of purchasing agent are as following.

The price tactics:

$$X_p^i = X_p^{i-1} + a_c\left(Y_p^{i-1} - X_p^{i-1}\right) \times \frac{X_p^{i-1}}{Y_p^{i-1}} \quad \textbf{(8)}$$

The quality tactics:

$$X_Q^i = X_Q^{i-1} - a_c\left(X_Q^{i-1} - Y_Q^{i-1}\right) \times \frac{Y_Q^{i-1}}{X_Q^{i-1}} \quad \textbf{(9)}$$

In the formula, i =2, $\cdots$, n. a_c: represents the degree of risk appetite or patience of purchasing agent. That is, the higher for risk appetite of purchasing agent, the larger for a_c. The much higher for the degree of patience, the smaller for a_c. When $i = 1$, the offer combination of purchasing agent is: $X^1=\left(X_p^1,X_Q^1\right)$.

The offer tactics of supplier agent are as following.

The price tactics:

$$Y_p^i=Y_p^{i\text{-}1}-a_s\left(Y_p^{i\text{-}1}-X_P^{i\text{-}1}\right)\times\frac{X_p^{i-1}}{Y_p^{i\text{-}1}} \quad \textbf{(10)}$$

The quality tactics:

$$Y_Q^i=Y_Q^{i\text{-}1}+a_s\left(X_Q^{i\text{-}1}-Y_Q^{i\text{-}1}\right)\times\frac{Y_Q^{i-1}}{X_Q^{i\text{-}1}} \quad \textbf{(11)}$$

In the formula, i=2, $\cdots$, n. a_s represents the degree of risk appetite or patience of supplier agent. That is, the more for risk appetite of supplier agent, the bigger for a_s. The more greater for the degree of patience, the smaller for a_s. When $i=1$, the offer combination of supplier agent is: $Y^1=\left(Y_p^1,Y_Q^1\right)$.

At the time $t=t_i$, the behavior of purchasing is as following.

$$A^c\left(t_i,X_{c\to s}^i\right)=\begin{cases} Quit & t>T^{Max} \\ Accept & N\left(Y^i\right)\ge N\left(X^i\right) \\ Offer\left(X^{i+1}\right) & N\left(Y^i\right)<N\left(X^i\right)\end{cases} \quad \textbf{(12)}$$

At the time $t=t_i$, the behavior of supplier is as following.

$$A^s\left(t_i,Y_{s\to c}^i\right)=\begin{cases} Quit & t>T^{Max} \\ Accept & G\left(X^i\right)\ge G\left(Y^i\right) \\ Offer\left(x^{i+1}\right) & G\left(X^i\right)<G\left(Y^i\right)\end{cases} \quad \textbf{(13)}$$

In the formula, T^{Max} represents deadline that purchasing agent and supplier agent will complete negotiation and reach agreement.

3.3 Negotiation Procedure

There does exist one purchasing agent and lots of supplier agent ($Y^1=\left(Y_p^1,Y_Q^1\right)=\left(480,95\%\right)$) that is suitable for negotiation in manufacturing enterprise supply chain. The sort is set according to the given utility of supplier and meet $G\left(n_1\right)>G\left(n_2\right)>\cdots>G\left(n_l\right)$, the negotiation procedures can be drawn as follows. The negotiation process is as shown in Figure 2.

Step 1. At time $t=t_1$, the two sides begin to negotiate. Purchasing agent must meet $N\left(Y^2\right)\le N\left(X^1\right)$, and supplier agent must meet $G\left(X^2\right)\ge G\left(Y^1\right)$, and the supplier that cannot satisfy the conditions will be eliminated. And then the purchasing agent will negotiate with supplier agent($n_1,n_2,\cdots n_{l_1}$, $l_1<l$). If $G\left(X^i\right)\le G\left(Y^{i-1}\right)$, turn to step 5.

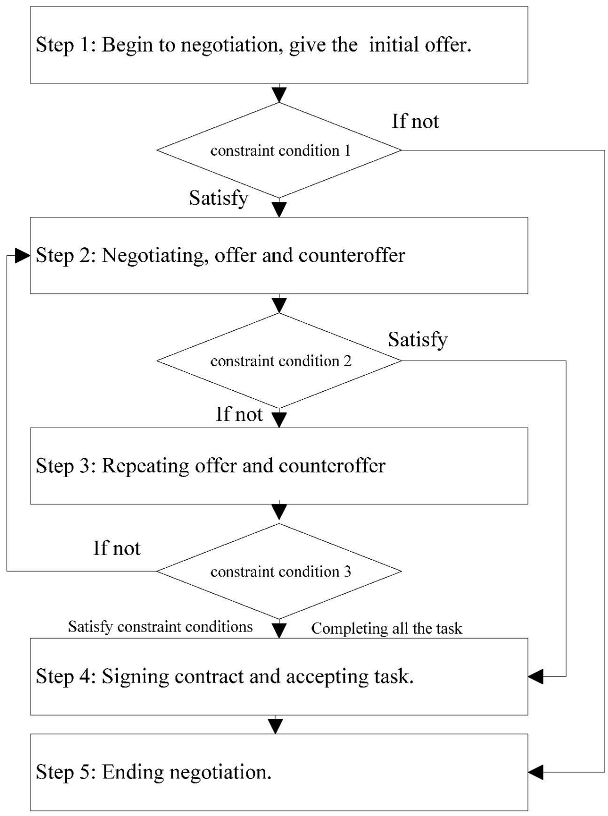


Figure 2. Data graph of negotiation both sides

Step 2. Set up $l_m\left(l_m<l\right)$ as the number of supplier agent that can negotiate with purchasing agent in multi-agent system of manufacturing enterprise supply chain. At time $t=t_i$ (i=2, $\cdots$, n), when both parties meet $N\left(Y^i\right)\le N\left(X^{i\text{-}1}\right)$ and $G\left(X^i\right)\ge G\left(Y^{i\text{-}1}\right)$, supplier of satisfying the conditions will gain the supply quantity that is decided by the supply quota coefficient. If $M_D=\sum_{i=1}^{l<m}\beta\left(Y_D^{n_{l_1}}\right)$, then turn to step 4. In the formula, M_D is the all quantity that purchasing agent needs. $Y_D^{n_{l_1}}$ is the supplying quantity of supplier agent l_1 in the delivery time. β is the supply quota coefficient of supplier agent l_1, in general, $\beta\in\left[0.3,0.7\right]$. This can prevent some unforeseen circumstances, for example, suppliers cannot timely supply in some unforeseen circumstances. This can reduce the risk of shortages. Different supplier has the different supply quota coefficient. For example, the supply quota coefficient of the supplier of the Philips Company is 0.3.

Step 3. If $M_D=\sum_{i=1}^{l<m}\beta\left(Y_D^{n_{l_1}}\right)$, purchasing agent will send termination message to supplier agent, then turn to step 4. If all the negotiation tasks are completed, the negotiation process is automatically stopped, and turns to step 5. If the negotiation task is not completed, repeat step 2 and step 3.

Step 4. Purchasing agent will contract with supplier

agent, supplier agent will accept the task.
Step 5. Ending negotiation.

4 Negotiation Illustration

In the multi-agent system of manufacturing enterprise supply chain, purchasing agent will negotiate with supplier agent about price and quality for certain raw materials and spare parts. The degree of risk appetite will affect the negotiation number, price and utility. The following example is to discuss their changes.

Given the initial offer combination of purchasing agent:

$$X^1 = \left(X_p^1, X_Q^1\right) = \left(400, 100\%\right).$$

Given the initial offer combination of supplier agent:

$$Y^1 = \left(Y_p^1, Y_Q^1\right) = \left(480, 95\%\right).$$

In the negotiation process, the participants will make an offer combination according to their respective offer tactics, the change of a_c and a_s will affect the negotiation process. By means of VB and MATLAB, there are 3 different situations will be discussed to clearly state the changes.

(1) a_c=0.2 and a_s=0.2

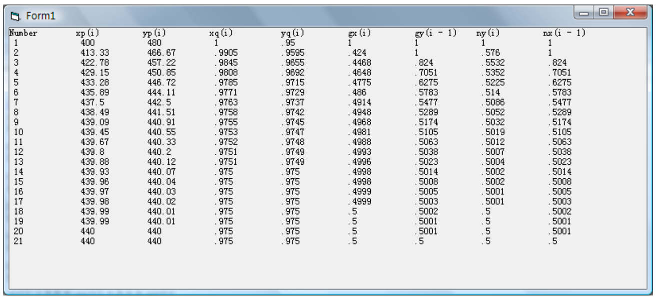
The initial offer combination of purchasing agent is $X^1 = \left(X_p^1, X_Q^1\right) = \left(400, 100\%\right)$, and the degree of risk appetite of purchasing agent is a_c=0.2. The initial offer combination of supplier agent is $Y^1 = \left(Y_p^1, Y_Q^1\right) = \left(480, 95\%\right)$, and the degree of risk appetite of purchasing agent is a_s=0.2.

In this case, purchasing agent and supplier agent are neither appetite for risk, they will negotiate according to the negotiation procedure, and the specific negotiation process is as showed in Figure 3-1 and Figure 3-2. If the conditions are meet $N\left(Y^i\right) \le N\left(X^{i-1}\right)$ and $G\left(X^i\right) \ge G\left(Y^{i-1}\right)$, the negotiation is to end. In Figure 3-2, the position point of appearing symbol ∗ at first time is the end point of negotiation. In the figure, X-axis represents the negotiation times, Y-axis represents the negotiated price, Z-axis represents the quality requirement.

The negotiation times are 21, the negotiated transaction price is 440, the negotiated transaction quality is 0.975. The utility of offer combination of purchasing agent and supplier agent is the same.

The utility of offer combination of purchasing agent is:

$$N\left(X^{21}\right) = w_g^p N_p\left(X_p^{21}\right) + w_g^Q N_Q\left(X_Q^{21}\right) = 0.5$$


Form1

Number	xp(i)	yp(i)	xq(i)	yq(i)	gx(i)	gy(i - 1)	ny(i)	nx(i - 1)
1	400	480	1	.95	1	1	1	1
2	413.33	466.67	.9905	.9595	.424	1	.576	1
3	422.78	457.22	.9845	.9655	.4468	.824	.5532	.824
4	429.15	450.85	.9808	.9692	.4648	.7051	.5352	.7051
5	433.28	446.72	.9785	.9715	.4775	.6275	.5225	.6275
6	435.89	444.11	.9771	.9729	.486	.5783	.514	.5783
7	437.5	442.5	.9763	.9737	.4914	.5477	.5086	.5477
8	438.49	441.51	.9758	.9742	.4948	.5289	.5052	.5289
9	439.09	440.91	.9755	.9745	.4968	.5174	.5032	.5174
10	439.45	440.55	.9753	.9747	.4981	.5105	.5019	.5105
11	439.67	440.33	.9752	.9748	.4988	.5063	.5012	.5063
12	439.8	440.2	.9751	.9749	.4993	.5038	.5007	.5038
13	439.88	440.12	.9751	.9749	.4996	.5023	.5004	.5023
14	439.93	440.07	.975	.975	.4998	.5014	.5002	.5014
15	439.96	440.04	.975	.975	.4998	.5008	.5002	.5008
16	439.97	440.03	.975	.975	.4999	.5005	.5001	.5005
17	439.98	440.02	.975	.975	.4999	.5003	.5001	.5003
18	439.99	440.01	.975	.975	.5	.5002	.5	.5002
19	439.99	440.01	.975	.975	.5	.5001	.5	.5001
20	440	440	.975	.975	.5	.5001	.5	.5001
21	440	440	.975	.975	.5	.5	.5	.5

Figure 3-1. Data graph of negotiation both sides (a_c = 0.2 and a_s = 0.2)

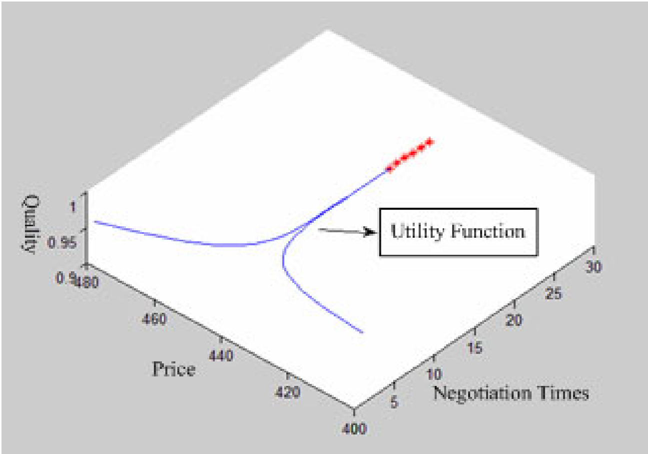


Figure 3-2. Negotiation process diagram (a_c = 0.2 and a_s = 0.2)

The utility of offer combination of supplier agent is:

$$G\left(Y^{21}\right) = w_n^p G_p\left(Y_p^{21}\right) + w_n^Q G_Q\left(Y_Q^{21}\right) = 0.5$$

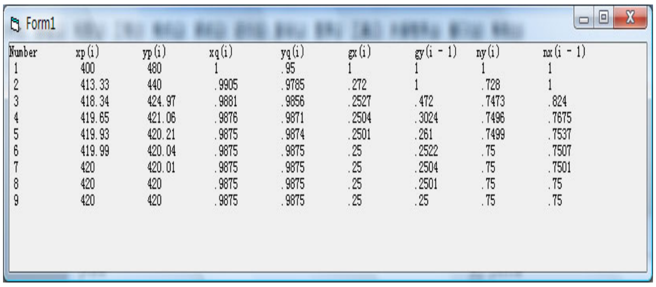
It can be viewed when purchasing agent and supplier agent are neither appetite for risk, they will make small concessions for each negotiation, which maybe lead to negotiating many times and reach the final agreement.

(2) a_c = 0.2 and a_s = 0.6

The initial offer combination of purchasing agent is $X^1 = \left(X_p^1, X_Q^1\right) = \left(400, 100\%\right)$, and the degree of risk appetite of purchasing agent is a_c=0.2. The initial offer combination of supplier agent is $Y^1 = \left(Y_p^1, Y_Q^1\right) = \left(480, 95\%\right)$, and the degree of risk appetite of purchasing agent is a_s=0.6.

In this case, purchasing agent has no appetite for risk and supplier agent has appetite for risk, they will negotiate according to the negotiation procedure, and the specific negotiation process is as showed in Figure 4-1 and Figure 4-2. The negotiation times are 9, the negotiated transaction price is 420, and the negotiated transaction quality is 0.9875. The utility of offer combination of purchasing agent and supplier agent is as following.

The utility of offer combination of purchasing agent is:



Number	xp(i)	yp(i)	xq(i)	yq(i)	gx(i)	gy(i - 1)	ny(i)	nx(i - 1)
1	400	480	1	.95	1	1	1	1
2	413.33	440	.9905	.9785	.272	1	.728	1
3	418.34	424.97	.9881	.9856	.2527	.472	.7473	.824
4	419.65	421.06	.9876	.9871	.2504	.3024	.7496	.7675
5	419.93	420.21	.9875	.9874	.2501	.261	.7499	.7537
6	419.99	420.04	.9875	.9875	.25	.2522	.75	.7507
7	420	420.01	.9875	.9875	.25	.2504	.75	.7501
8	420	420	.9875	.9875	.25	.2501	.75	.75
9	420	420	.9875	.9875	.25	.25	.75	.75

Figure 4-1. Data graph of negotiation both sides (a_c = 0.2 and a_s = 0.6)

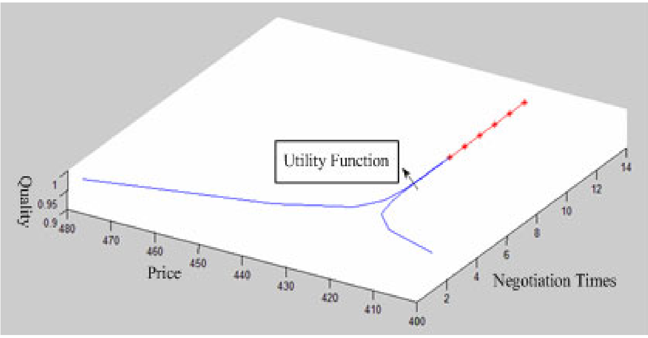


Figure 4-2. Negotiation process diagram (a_c = 0.2 and a_s = 0.6)

$$N\left(X^9\right) = w_g^P N_p\left(X_p^9\right) + w_g^Q N_Q\left(X_Q^9\right) = 1$$

The utility of offer combination of supplier agent is:

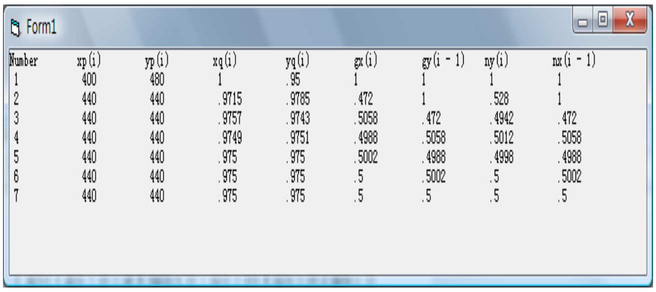
$$G\left(Y^9\right) = w_n^P G_p\left(Y_p^9\right) + w_n^Q G_Q\left(Y_Q^9\right) = 0.25$$

It can be viewed that, for the reason of purchasing agent has no appetite for risk and supplier agent has appetite for risk, the time of negotiation is decrease significantly, the final transaction price and quality are conducive to purchasing agent, and the difference of utility between the two sides is quite large.

(3) a_c = 0.6 and a_s = 0.6

The initial offer combination of purchasing agent is $X^1 = \left(X_p^1, X_Q^1\right) = (400, 100\%)$, and the degree of risk appetite of purchasing agent is a_c=0.6. The initial offer combination of supplier agent is $Y^1 = \left(Y_p^1, Y_Q^1\right) = (480, 95\%)$, and the degree of risk appetite of purchasing agent is a_s=0.6.

In this case, purchasing agent has all appetite for risk, they will negotiate according to the negotiation procedure, and the specific negotiation process is as showed in Figure 5-1 and Figure 5-2. The negotiation times are 7, and the negotiated transaction price is 440, the negotiated transaction quality is 0.975. The utility of offer combination of purchasing agent and supplier agent is as following.



Number	xp(i)	yp(i)	xq(i)	yq(i)	gx(i)	gy(i - 1)	ny(i)	nx(i - 1)
1	400	480	1	.95	1	1	1	1
2	440	440	.9715	.9785	.472	1	.528	1
3	440	440	.9757	.9743	.5058	.472	.4942	.472
4	440	440	.9749	.9751	.4988	.5058	.5012	.5058
5	440	440	.975	.975	.5002	.4988	.4998	.4988
6	440	440	.975	.975	.5	.5002	.5	.5002
7	440	440	.975	.975	.5	.5	.5	.5

Figure 5-1. Data graph of negotiation both sides (a_c = 0.6 and a_s = 0.6)

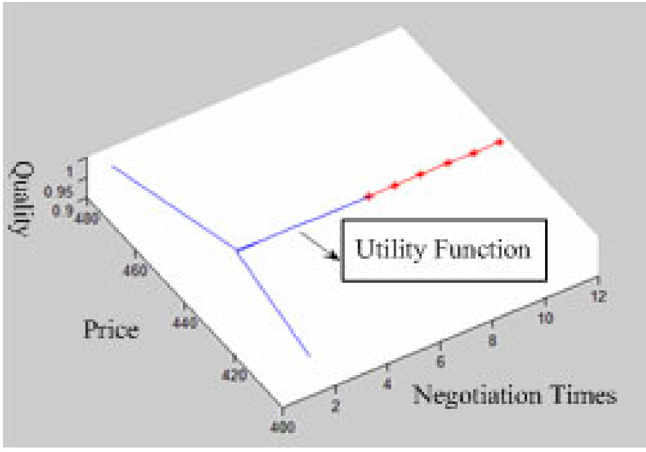


Figure 5-2. Negotiation process diagram (a_c = 0.6 and a_s = 0.6)

The utility of offer combination of purchasing agent is:

$$N(X^7) = w_g^P N_p(X_p^7) + w_g^Q N_Q(X_Q^7) = 0.5$$

The utility of offer combination of supplier agent is:

$$G\left(Y^7\right) = w_n^P G_p\left(Y_p^7\right) + w_n^Q G_Q\left(Y_Q^7\right) = 0.5$$

It can be viewed that, both sides will make greater concessions in the negotiation. It is not difficult to reach agreement. Table 1 is displaying the influence of the degree of risk appetite on the negotiation times, price, quality and utility.

Table 1. Influence of the degree of risk appetite

(a_c, a_s)	(0.2, 0.2)	(0.2, 0.6)	(0.6, 0.6)
Negotiation times	21	9	7
Transaction price	440	420	440
Transaction quality	0.975	0.9875	0.975
Utility	(0.5,0.5)	(1,0.25)	(0.5,0.5)

In the negotiation model, we mainly focus on the influence of risk preference on the negotiation process, and the different degree of risk preference has different effects on the negotiation process. It can be drawn from Table 1, if the negotiating sides have appetite for risk, the negotiation times are the least and the utility is the largest. If neither side of negotiation has appetite for risk and both sides are very cautious, the change of price and quality is very small, so more consultations needed to reach an agreement. If one side has no appetite for risk, but the other has appetite for risk, so the utility of final offer combination is asymmetric, the utility of the side which does not have appetite for risk is much larger than the one has no appetite for risk.

5 Conclusion

(1) In the multi-agent system of manufacturing enterprise supply chain, the multi-objective negotiation between agents is a complex problem. In this paper, we presented a multi-objective negotiation model, and then discussed the negotiating tactics and steps between the agents. A given example is discussed for validating the negotiating model and tactics as well as the procedure. That will save negotiation time and improve negotiation efficiency, and optimize the supply chain management of manufacturing enterprise, and result to share their common profit in win-win way.

(2) In the future research, we mainly consider two aspects. First, on the basis of studying the two parties' negotiations, we conduct three party consultations or multi party consultations. In the actual supply chain operation, the negotiation about three parties or multi parties is widespread. Second, with the improvement of consumption level and application of Internet technology, manufacturing enterprise personalized product supply chain has become a trend, the negotiation is not the same between the personalized product supply chain multi-agent system and traditional manufacturing enterprise supply chain multi-agent system, this problem is worth studying. We would like to cooperate with researchers in this field to carry out such research together.

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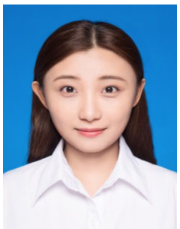

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