Dynamic Evolution Mechanism of Quality Negotiation Conflict in Complex Product supply chain under participants' Grey Preferences

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Abstract: A novel graph model for conflict resolution was developed in the condition that decision-makers' preference on states were not precisely determined in the Quality Negotiation stage in Complex Product supply-chain cooperation, in which the probabilities of grey number comparison were introduced to reflect participants hesitation for state priority. Specially, Petri net was utilized to describe the conflict evolutionary, which contained stage set, transition trigger and explosion rule. Grey numbers were used to reflect participants' uncertain preference on several states and the probability of Petri net expansions can be calculated by comparing uncertain numbers. The equilibrium achieving condition were studied in the framework of Petri net, which can give direct proof for predicating potential Conflict solutions. The case of airframe quality standard in the negotiation stage of a certain commercial aircraft in China was conducted to reflect the feasibility and effectiveness of the previous model and method.

1. Introduction

Complex Product refers to a class of large products, systems or infrastructure with high technology, high integration of parts and components, complex production process and extremely high difficulty of operation, single or small batch customized production. Complex products mainly adopt "Main Manufacturer-Supplier", in the M-S production mode, the main manufacturer and the supplier negotiate on the quality requirements and price of the products. In the process of negotiation, both parties are easy to have disputes on the product quality standards. Therefore, the main manufacturer needs to grasp the quality conflict that may occur in the contract negotiation process as a whole, analyze the current situation and participants' preferences, and lay a solid theoretical foundation and designing the dispute solution pertinently.

Conflict analysis theory is an important branch of generalized game theory. The extension and application of conflict analysis in various fields has always been a hot topic of foreign scholars. Ding and Kang put forward the concept of grey intensity preference under the theoretical framework of grey preference[1]. In the field of Petri net application, Liu designed a dynamic conflict analysis Petri net with time parameters according to the characteristics of Petri net and conflict analysis theory[2]. In the application field of conflict analysis graph theory model, Yu et al. used the graph model theory and the decision-maker attitude analysis method to study the influence of the decision-maker's attitude in conflict on the determination of preference information and conflict results[3]. In the framework of graph model, Wu et al. Established a matrix formula to model and analyze the conflicts that decision makers may have interaction preferences[4]. Hou and

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Xu extended the strategy priority ranking method under simple preference to intensity preference[5].

It is not difficult to see from the relevant literature in this field at home and abroad, the existing literature provides a good theoretical basis and analysis method for this topic. However, for the quality conflict in the process of complex product contract negotiation, the previous analysis is mainly based on the state preference information determined by the participants. In reality, the participants may not be able to determine the preference order of the conflict development state. Based on the above considerations, this paper introduces the Petri net model under grey preference net model and conflict analysis theory are combined to construct a new type of conflict analysis graph theory model; each state in the process of conflict analysis is explored The steady-state situation and realization conditions provide predictive guidance for the possible development trend of conflict evolution in the future.

2. Petri net model of quality conflict in contract negotiation process

2.1. Design of Petri net model framework for quality conflict analysis

The traditional graph theory model of conflict analysis can be regarded as a set of four elements:[N，S，$(A_i)_{i\in N}$，$(\succ_i, \sim_i)_{i\in N}$][6].Petri net is a kind of symbolic, visual and structured graph theory analysis model which can be used to describe the state and internal evolution process.In order to use Petri net to analyze a conflict process, a new type of Petri net for conflict analysis (PNCA) model can be refer to [7].

2.2. PNCA model generation algorithm

Definition 1 For a decision maker, if more benefits can be obtained through state movement, the movement can be called the unilateral improvement ; if the movement can be moved from one state to another, then the movement is called the unilateral move of the decision maker.

The algorithm of PNCA generation can be summarized (refer to [8]). Based on the above ideas, the flow chart of PNCA generation algorithm is designed, as shown in Figure 1.

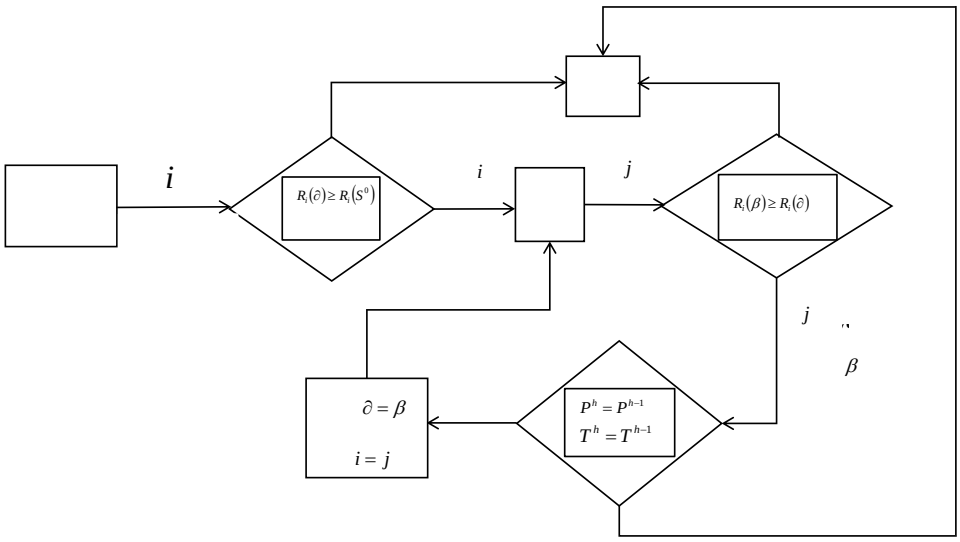

Figure 1 Flow chart of PNCA generation algorithm

3. Quality conflict equilibrium analysis of complex product contract negotiation process based on PNCA model

3.1. Equilibrium definition

Assuming that the unilateral improvement and unilateral movement of the decision maker from the node K are $S_i^+(K)$ and $S_i(K)$ respectively, two kinds of commonly used stability concepts are introduced as follows:

Def 2 Let $\forall_i \in N$. A state K is Nash stable (R) for player i if $S_i^+(k)=\phi$.

Def 3 For $\forall_i \in N$, a state K is general meta-rational (GMR) for player i if for every $k_1 \in S_i^+(k)$ there exists at least one $k_2 \in S_j(k_1)$ with $R_i(k_2) \le R_i(k)$.

Assumes that a PNCA model contains many chains or paths λ_i （i=1，2，…）, The equilibrium solution of PNCA model can be obtained at the termination node of each path and Nash stability can be achieved at the termination node.

3.2. Decision maker's state transition rule under grey uncertain preference

Definition 4 Grey number size comparison rules

Suppose $a=\left[a^-,a^+\right]$, $b=\left[b^-,b^+\right]$,and remember $l_a=a^+-a^-$, $l_b=b^+-b^-$, then called $P(a\ge b)=\dfrac{\min\left\{l_a+l_b,\max\left(a^+-b^-,0\right)\right\}}{l_a+l_b}$ is the possibility degree of $a\ge b$,And the order relation is $a \underset{p}{\ge} b$.

When the decision-maker's preference is uncertain at a certain node of Petri net, the grey number is set first, and then it is expanded in different cases under the grey number comparison probability, and the realization conditions of equilibrium in different cases are considered respectively.

4. Case study

4.1. Case background

A commercial aircraft manufacturing (M) and airframe supplier (S) carry out quality cooperation on horizontal tail preparation. The main manufacturer follow the concept of “building world-class trunk aircraft” and put forward quality standards exceeding the average requirements of the industry to the suppliers. Affected by the earthquake in a certain area, part of the high-precision equipment of the engine body supplier suffered serious damage, and may not be able to achieve higher quality standards. Therefore, the supplier hopes to reduce the quality requirements to an acceptable level to ensure normal cooperation. However, the main manufacturer is not willing to accept this kind of requirement. As a third-party manager, the Ministry of industry and information technology (A), the superior department of the two sides, hopes that the two sides can negotiate harmoniously to solve the above disputes, and is even willing to coordinate and promise to provide some preferential policies for the two sides to solve the disputes on quality standards. Specifically, suppliers can take the following three kinds of actions: to reduce the product quality standard appropriately (C_1), to maintain a higher product quality standard (C_2) and to terminate the negotiation (C_3); the main manufacturer has two alternative strategies: accept the product (C_4) and stop ordering (C_5); MIIT

can choose whether to coordinate (C_6). The above analysis shows that the possible actions taken by all parties may lead to the above quality conflict reaching different states.

Since there are three decision makers and six choices, however, each decision maker can only choose one strategy at a time. In addition, if the supplier chooses C_3, the negotiation will come to an end, and there is no need for MIIT to coordinate. Therefore, there are only 12 feasible decision States, as shown in Table 1; the preference information of each decision maker for all States can be obtained, as shown in Table 2.

Table 1 Feasible state of quality conflict in negotiation process

Status serial number		1	2	3	4	5	6	7	8	9	10	11	12
S	C_1	N	Y	N	Y	N	Y	N	Y	N	Y	N	—
	C_2	N	N	Y	N	Y	N	Y	N	Y	N	Y	—
	C_3	N	N	N	N	N	N	N	N	N	N	N	Y/N
A	C_4	N	N	N	Y	Y	N	N	Y	Y	N	N	—
M	C_5	N	N	N	N	N	Y	Y	Y	Y	N	N	—
	C_6	N	N	N	N	N	N	N	N	N	Y	Y	—

Table2 Subjective preference ranking for each state

Participants	State preference ranking
S	6>8 > 4>2 > 11>1>7>9 > 3>5>10
A	7>6>9>8>3>2>5>4>10
M	7>9>5>3>（4>2、10）>8>6>11

4.2. Evolutionary of Petri net model

Since the main manufacturer's preference ranking for 10, 4 and 2 is uncertain, now we set grey number to discuss the implementation of Petri net expansion and equilibrium in different situations:

Case 1：let $\otimes_1$ represent the preference value of State2, $\otimes_2$ represent the preference value of state10, and order $\otimes_1 = [2.4,2.7], \otimes_2 = [2.3,2.5]$ then $p(\otimes_1 \geq \otimes_2) = 0.8$.

(1) if $\otimes_1 \geq \otimes_2$,the preference order of the main manufacturer is:7>9>5>3>4>2>10>8>6>11.

Let P_i (S_j) denote the node of the i-th occurrence, S_j denote the state of the node, and tm (C_n) denote the transition of the m-th occurrence of the policy C_n. The PNCA model generation process can be summarized as follows:

① When the main manufacturer puts forward higher quality standards, the supplier should first judge whether it needs to move from the initial S_1 to other states according to its own situation. For suppliers, S_1 can be moved to two downstream States, namely S_2 and S_3. According to the subjective preference of the supplier for each state, the results can be obtained $2 \succ_s 1 \succ_s 3$. Therefore, if the supplier chooses to move to S_2 and does not move to S_3, the path $S_1 \rightarrow S_3$ is pruned.

② Because the same decision maker cannot move twice in a row, in S_2, the main manufacturer or A needs to make a decision. If A makes a decision, because the only downstream state is 4 and $2 \succ_A 4$, A will not choose to move to S_4. If M makes a decision, because $2 \succ_M 10$ and $2 \succ_M 6$, M will not choose to move to S_{10} and S_6, the paths $S_2 \rightarrow S_{10}$ and $S_2 \rightarrow S_6$ are pruned.

③ At this time, no new nodes and new changes appear, and the final Petri net model is obtained, as shown in the figure2 below.

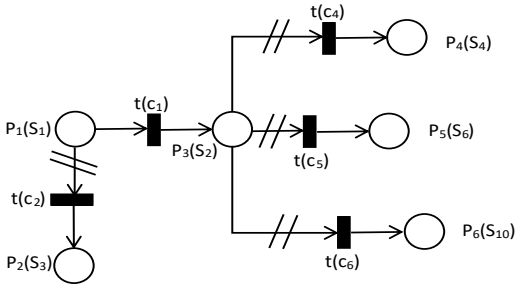

Figure2 Schematic diagram of PNCA model generation

Case 2：let $\otimes_3$ represent the preference value of State4, $\otimes_2$ represent the preference value of state10, and order $\otimes_3 = [2.5,2.7]$, $\otimes_2 = [2.6,2.9]$. then $P(\otimes_2 \geq \otimes_3) = 0.8$.

(2) if $\otimes_2 \geq \otimes_3$,the preference order of the main manufacturer is:7>9>5>3>10>4>2>8>6>11.

In this case, the PNCA model generation process are the same as above, and the final Petri net model as shown in the figure3 below.

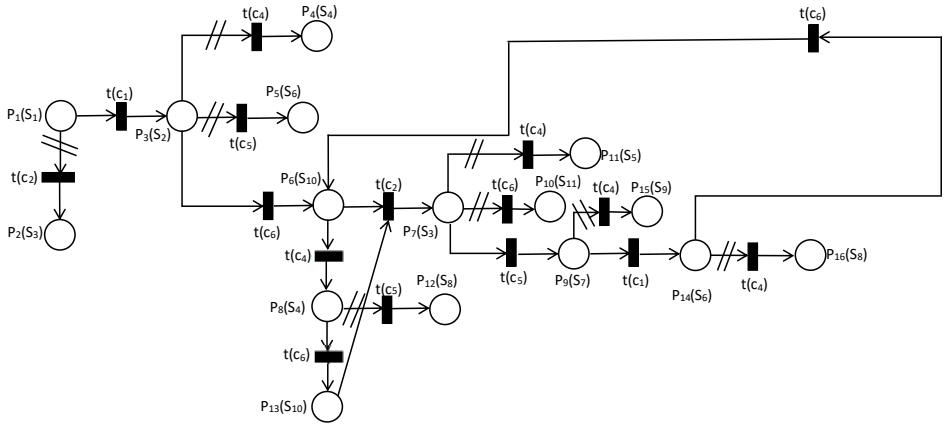

Figure3 Schematic diagram of PNCA model generation

4.3. Equilibrium of the quality negotiation conflict

（1）In case1,at S_2, the supplier expects to reduce the quality standard appropriately, and M will not easily agree without the coordination of MIIT. That is, in the case of considering only Nash equilibrium, case 1 achieves Nash equilibrium at S_2.

（2）In case2, the possible equilibrium points are S_3 and S_7.

①At S_3, in order to avoid paying a large amount of liquidated damages, the supplier will maintain the requirement of high quality standards. Although M does not take action in a short period of time, M will choose to buy high-quality products that meet their own requirements, so that the negotiation can reach an agreement.

②At S_7, M choose to buy high-quality products that meet their own requirements and reach an agreement through negotiation.

According to the above results, if all participants are rational people, nodes P_2 and P_3 will not exist for a long time, which belongs to short-term equilibrium. In the long-term waiting, participants will rationally choose to “C_3” or “C_5”, which makes the cooperation abortion. In the long-term evolution process, the decision-making process of the participants must reach node P_9, that is, to

achieve the long-term equilibrium of state S_7. Under the condition that the A does not need to coordinate, the suppliers maintain high-quality product standards, M continue to purchase according to the contract, and the two sides maintain a good strategic partnership, so as to solve the disputes with the highest overall interests and achieve a win-win situation.

5. Conclusion and Future Works

In order to capture the uncertainty of products, this paper uses Petri net model under grey preference to establish a new graph theory model of conflict analysis, which helps manufacturers of complex products to study the evolution trend of quality conflict, discusses the steady-state and implementation conditions of conflict analysis, and provides predictive guidance for the possible development trend of conflict evolution in the future.

The Petri net model of conflict analysis under grey preference designed in this paper is not only a beneficial development and supplement to the theory, but also an effective method and tool for dealing with quality disputes in the negotiation stage of complex products. In addition, the decision-making process of participants may involve dynamic time evolution and resource constraints. How to reflect the decision-making time and other related information in the transition information of Petri net is an important direction that this paper can further study in the future.

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