Goal Conflict Management of Construction Projects Based on Game Theory

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Abstract
In the process of project construction, problems from the target control can cause conflict because of conflicts between the owner and the contractor, such as quality, cost and est. It will eventually lead to deviation from the objectives of the project or even failure, if the conflict cannot be promptly and effectively addressed. This paper introduces the theory of game theory, to study the evolutionary stable strategy of owner and contractor in the conflict management by establishing a model of static game of complete information to simulate the process of conflict. Some practical guidance on effectively conflict management was proposed by the analysis of static and evolutionary game theory.
Key words: GAME THEORY, CONFLICT MANAGEMENT, BEHAVIOR STRATEGY

Introduction

Construction projects involve multiple stakeholders who have different aspirations and expectations of interest, especially the owner and contractor are most closely. Their intimate relationship determines can directly affect the projects smoothly. Conflict in construction projects is often the result of different notions between different sides in progress, such as quality, cost and others result in the process of interaction in the construction process [1]. And Jehn put forward to the notion that the different goals of the parties are likely to lead to conflicts [2]. All the conflicts will impact the schedule, quality; cost and some others, even leading to fail or loss, if it should not be resolved timely and effectively. Therefore, if the construction project between the owners and the constructors exist effective conflict resolution mechanism, it is a worthy of study whether the target conflicts can be effectively resolved.

In construction project, differences in different aspects including structure, project status, thinking angle lead to the differences of project decisions. Wall and Canister think that one party perceives their interests opposed by other negative effects, and it is a process that they feel about the other side has a negative impact on their concern [3]. Frank and Jehn regard relationship conflicts between members as intermediary variables to investigate on the quality of the decision task conflict; Found in the process of task

conflict, members of relationship conflicts existed between perception and members of interpersonal conflict would increase the stiffness of members of the decision-making, thus reduce the decision quality [4]. In project conflict, cognitive differences are inevitable, often involves task-oriented conflict and relationship conflict, the former focuses on the controversy about material benefits, the latter focuses on the interpersonal relationship [5]. Rahim study found that, compared with Americans, Chinese attached great importance to the relationship, and is easier to take the way of avoiding conflict; Chow and Ding study Chinese common way avoiding to obtain a better opportunity [6]. Therefore, the research for the management in construction project goal conflict should use the psychology of cognitive theory, enrich and perfect project conflict management theory and method system.

Game theory is the study of rational behavior of individuals or organizations in the cross decision theory [7], which is a method based on mathematics exploring how to maximize the effectiveness of stakeholders. In recent years, more and more scholars put the game theory in the study of construction project management. Long made use of game theory, constructed the model of rational choice between the individual, department and group conflicts, pointing out that conflicts often occurred in the process of mixed game [8]. Through the discussion of the zero-sum game problem, Gary studied how to collect the construction technology measures and methods in the construction work [9]. Lazar studied the owner and constructor in the prisoner's dilemma game scene, and put forward the successful solution to the conflict [10]. In applications, through the establishment of general evolutionary game model of single and multiple groups, Friedman formally applied evolutionary game theory in economics, which lay the foundation for using of evolutionary game theory to the practice [11-12]. Based on the research of Friedman, scholars have been applying evolutionary game theory to the marketing, industry economics, social norms, public management, and other fields. However, due to the owner and the contractor mutually cooperate, friction between the two sides tend to evolve to the dispute [13]. The negative relationship between owner and contractor caused not only the construction period, quality, cost control, such as difficult to achieve, also produce a large number of additional costs. Therefore, evolutionary game can be used in the construction of conflict management. However, related studies on the evolution of conflict management, game is relatively less. On the basis of previous studies, in this paper, the methods for the treatment goal conflict research innovation: use the method of combining static game and evolutionary game: use the method of combining static game and evolutionary game.

According to the related research results as the theoretical basis, this paper introduced evolutionary game theory and conflict analysis, to grasp the evolution regularity in construction engineering project goal conflict. This paper will study the optimal solution of the problem of conflict management between the owner and contractor, and build conflict management mechanism to explore the more effective conflict management by the static game and evolutionary game analysis. The evolutionary game model is applied to the construction of conflict management, to reduce the negative impact of the conflict on the relationship between different teams, that the game theory analysis of the findings are much more practical and realistic significance than before.

Model Assumptions

A mathematical model of conflict between on the goals of owners and contractors should be built before study, which is based on four-point hypothesis.

(1) Both owners and contractors are not only rational economic man, but utility maximization.

(2) Both owners and contractors have access to complete information, and their interests are in conflict and will not appear conspiracy phenomenon.

(3) The purpose of the game analysis is to predict how owners and contractors will do in the equilibrium state, according to the rules of the game.

(4) Contractor is risk aversion, owners is risk-neutral.

It can predict when and which behaviors is optimal under the Nash equilibrium game model of mixed strategy [14] in the situations of the initial project goal conflict by building a mathematical model of complete information static game, analyzing the utility function of both sides action. In many conflicts between the two sides game analysis, ESS expressed limited and stable rationality in strict Nash equilibrium [15].

Take the conflict game between owners and contractors for example, while owners choose mixed strategy, the contractor also choose the same.

Expected utility of the owner is

$$E_{V_1}(\sigma_1, \sigma_2) = \sum_{k=1}^{K} \sum_{j=1}^{J} \sigma_{1k} \sigma_{2j} \mu_1(s_{1k}, s_{2j}) \quad (1)$$

Expected utility of the contractor is

$$E_{V_2}(\sigma_1, \sigma_2) = \sum_{k=1}^{K} \sum_{j=1}^{J} \sigma_{1k} \sigma_{2j} \mu_2(s_{1k}, s_{2j}) \quad (2)$$

The Way to Deal with Conflicts

Existing research shows that different individuals or organizations will take different management actions to deal with conflicts in the project. C.K.W. deDreu divided conflict management into two dimension: Arbitrary (to meet their own profit motive) and Cooperation (to meet the interests of the other motives) [16]. Based on the above two classifications, the assumption of owner's action strategy is sure or not sure, Corresponding, the assumption of contractor's action strategy is cooperation or non-cooperation[17]. Based on the above analysis of the dimension, a simple complete information static game model between owner and contractor was built.

Conflict treatments have been discussed in various kinds of studies. Mehta divided conflict management into five different conflict coping strategies, which are forced, withdraw, accommodate, compromise, cooperation [18]. In the field of construction project, one party can't force the other to perform the job, so the conflict management results are generally classified as collaboration, withdraw, accommodate, compromise. Figure 1 is a phase diagram of a certain degree of owners and the cooperation degree of contractors corresponding.

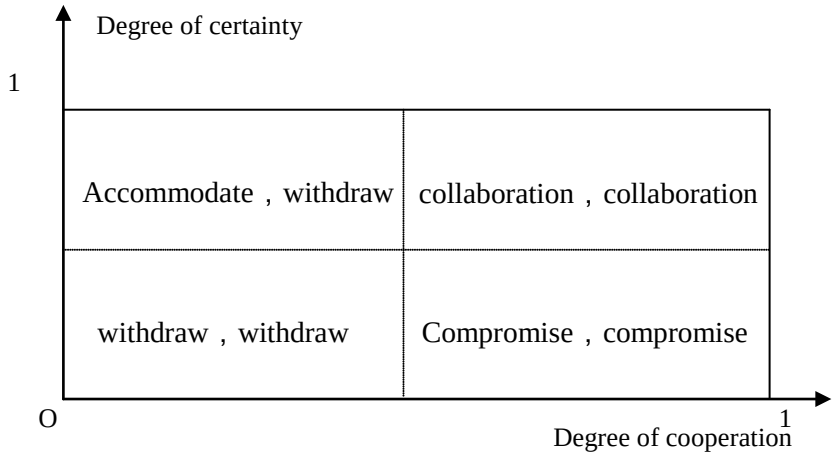

Figure 1. Phase diagram of certainty degree and cooperation degree

It is assumed that the contractor is risk aversion, and the owner is risk neutral. When the owner chooses certain behaviors, and the contractor chooses cooperate action corresponding, both sides will take the mutual coordination strategy. While the owner chooses certain behaviors, and contractor chooses non-cooperate actions, the owner have to make a compromise in order to avoid delays, because the contractor will choose withdrew strategy so as to guarantee return and avoid risk. When the owner chooses negation behavior, and contractor chooses cooperate action, the owner will choose to compromise due to the risk neutral to consider contractor's capacity. While the owner chooses negation behavior, and contractor chooses non-cooperate action, both sides will withdraw because neither can meet their needs.

Figure 2 shows a conflict matrix based on complete information static game model.

		contractor	
		cooperation	Non-cooperation
owner	affirmation	Collaboration , collaboration	Accommodate , withdrawing
	negation	compromise , compromise	withdrawing , withdrawing

Figure 2. Conflict matrix based on complete information static game model I

Psychological Compensation Utility of Goal Conflict

According to previous research results, this paper applies the psychological compensation

effect in the management psychology in the process of both owner and contractor in game. In the game process of the owner and the contractor, Psychological Compensation Utility is a kind of mental compensation effect by arguments to prove self-conscious and maintain their own rights and interests, to vent anger with the other's mistake to eliminate negative psychological impact at the same time in relationship conflict [19]. Mental compensation effect is an extension of the Psychological concept of elasticity; mental compensation effect will change with the process of project goal conflict management. Studies have shown that mental compensation effect related with cooperative supports and conflicting frequency. Mental compensation effect monotonically increased with supports and frequency, and marginal effect gradually decreased [20].

This paper assumed that h_1 is the owner's mental compensation effect and h_2 is the contractor's. When the owner chooses to affirm and the contractor chooses to non-cooperate, the contractor would gain mental compensation effect from fighting with the owner or its compromising. Meanwhile, the owner will lose its mental compensation effect since owner compromise before. Therefore, the contractor gains $h_2$and the owner gains $-h_1$. Similarly, when the owner chooses negation and the contractor chooses to cooperate, the owner will gain h_1 and the contractor will gain$-h_2$.

Static Game Analysis of Initial Conflict

A complete information static game model of goals conflicting between the owner and the contractor will be established. It assumed that the owner's earnings is V_1, and the contractor's income is V_2. Here the utility function of cost-benefit refers to opportunity cost. The economic cost from the owner and the contractor could make use of the concept about currency cost to express Y_1 and Y_2:

The owner's economic cost in conflict management is Y_1:

$$Y_1 = -e_1 s_{conflict} = -e_1(T_{time} + C_{cost} + Qquality \quad (3)$$

The contractor's economic cost in conflict management is Y_2:

$$Y_2 = -e_2 s_{conflict} = -e_2(T'_{time} + C'_{cost} + Qquality' \quad (4)$$

In the formula, e_1, e_2 represent respectively influence coefficient of the conflict cost by means of owner's and contractor's efforts to achieve collaborative. T_{time}, T'_{time} refer to time cost respectively, which caused by the conflict due to the schedule problem. C_{cost}, C'_{cost} are economic cost, which caused by the conflict with unreasonable construction program. $Q_{quality}$, $Q'_{quality}$ are economic loss which are caused by project qualities.

According to the assumption and model all above, there are 4 kinds of deal with conflict behavior between the owner and the contractor to discuss their crossed decision. As shown in figure 3, when the owner chooses to affirm and the contractor chooses to collaborate, both sides are win-win because of cooperation, then their utility are respectively V_1 andV_2. When the owner chooses to affirm and the contractor chooses non-collaboration, the contractor's utility is negative number, referred as $-V_2$, because the cost-profit of utility function is the opportunity cost. At the same time, the owner will give some mental compensation effect to the contractor because of their compromising; therefore, both sides spend a little coordination costs to deal with conflict, accordingly, their utility are $V_1 - Y_1 - h_1$ and$-V_2 - Y_2 + h_2$. While the owner chooses negation behavior, but the contractor chooses to collaborate, the contractor will give some mental compensation to the owner because of their benefits, and both of them will spend some money to solve the conflict, their utility are separately$-V_1 - Y_1 + h_1$ and$V_2 - Y_2 - h_2$. If the owner chooses negation strategy and the contractor chooses non-cooperation behavior, both of them will pay high to deal with the conflict by reason of the failure of conflict coordination, and both sides can hardly get any mental compensation from each other, correspondingly, their utility are $-V_1 - Y_1$ and $-V_2 - Y_2$.

		Contractor（risk aversion）	
		cooperation（p）	Non-cooperation（1-p）
Owner（risk neutral）	affirmation（q）	V_1，V_2	$V_1 - Y_1 - h_1$，$-V_2 - Y_2 + h_2$
	Negation（1-q）	$-V_1 - Y_1 + h_1$，$V_2 - Y_2 - h_2$	$-V_1 - Y_1$，$-V_2 - Y_2$

Figure 3. Conflict matrix based on complete information static game model II

The analysis of the owner's expected utility

Bring each cross decision according to the conflict matrix from figure 3 into the owner's expected function$E_{V_1}(\sigma_1,\sigma_2)$, it can get the owner's two expected utilities under the two decision of Affirmation and Negation strategy.

Expected utility when the owner chooses affirmation strategy is:

$$E_{V_{affirm}}(\sigma_1,\sigma_2) = pV_1 + (1-p)(V_1 - Y_1 - h_1) \quad (5)$$

Expected utility when the owner chooses negation strategy is:

$$E_{V_{negative}}(\sigma_1,\sigma_2) = p(-V_1 - Y_1 + h_1) + (1-p)(-V_1 - Y_1) \quad (6)$$

And the owner's average expected utility is:

$$\begin{aligned} E_{V_1}(\sigma_1,\sigma_2) &= q[pV_1 + (1-p)(V_1 - Y_1 - h_1)] \\ &\quad + (1-q)[p(-V_1 - Y_1 + h_1) \\ &\quad + (1-p)(-V_1 - Y_1)] \\ &= 2qV_1 + pqY_1 - qh_1 + ph_1 \\ &\quad - Y_1 - V_1 \\ &= (2q-1)V_1 - (1-pq)Y_1 + (p-q)h_1 \end{aligned} \quad (7)$$

The purpose of Conflict resolution is not the maximization of expected utility; the utility after the conflict resolution should be no less than reservation utility of decline conflict mediation, which refers to participation constraint in the theory of motivation（IR）[20].

Therefore, it can assume: $E_{V_1}(\sigma_1,\sigma_2) \geq -V_1 - Y_1 - h_1$

And to take the derivative of the objective function, $\max_q(2qV_1 + pqY_1 + ph_1 - qh_1 + h_1)$

Then, $\frac{\vartheta E_{v1}}{\vartheta q} = 2V_1 + pY_1 - h_1$

The first order condition, $p^* = -\frac{2V_1}{Y_1} + \frac{h_1}{Y_1}$ (8)

According to participation constraint（IR）applied in conflict management, $\max_q(2qV_1 + pqY_1 + ph_1 - qh_1 + h_1)$

When $p > -\frac{2V_1}{Y_1} + \frac{h_1}{Y_1}$, the owner will choose affirmation strategy;

If $p < -\frac{2V_1}{Y_1} + \frac{h_1}{Y_1}$, the owner may choose negation strategy;

While $p = -\frac{2V_1}{Y_1} + \frac{h_1}{Y_1}$, the owner can choose mixed strategy.

Take $Y_1 = e_1 s_{conflict} = e_1(T_{time} + C_{cost} + Q_{quality})$ into p^*

$$p^* = \frac{h_1 - 2V_1}{Y_1} = \frac{-h_1 + 2V_1}{e_1(T_{time} + C_{cost} + Q_{quality})} = \frac{h_1}{-e_1(T_{time} + C_{cost} + Q_{quality})} + \frac{2V_1}{e_1(T_{time} + C_{cost} + Q_{quality})} \quad (9)$$

If $\frac{V_n}{-Y_n}$ regards as marginal utility when a rational people choose whether he can cooperate or not (sure or not sure), that is he will get the rewards when every one unit the conflict cost increases or decreases, named income coefficient, saying a.

Similarly, $\frac{h_n}{Y_n}$ an be regarded as mental compensation benefit marginal utility when a rational people each unit conflict cost change, that is mental compensation coefficient, saying β.

It can draw a conclusion according to the above assumptions, $a_1 = \frac{V_1}{-Y_1} = \frac{2V_1}{e_1(T_{time} + C_{cost} + Q_{quality})}$ is the owner's income coefficient, and $\beta_1 = \frac{h_1}{Y_1} = \frac{h_1}{-e_1(T_{time} + C_{cost} + Q_{quality})}$ is the owner's coefficient of mental compensation coefficient.

(1) The owner trend to choose affirmation behavior and cooperation is preferred strategy in solving conflict problems if the owner's opportunity income and revenue coefficient increase.

(2) The owner will choose negative behavior caused by some factors out of control, such as quality, schedule and cost which are easy to result in the economic cost increasing. Therefore, the owner's compromising and the contractor's rational accommodation is priority strategy.

(3) The owner will tend to select compromise strategy to deal with conflict management if their income decreases, for the owner's efforts to resolve the conflict will result in their income coefficient reducing. Meanwhile, the contractor's hard-works for solving conflict will increase coefficient of mental compensation effect, which can prompt the contractor to choose cooperation behavior and the owner will choose compromise strategy.

(4) The owner's choice of certain behavior will promote the contractor tend to make cooperative decision, for the owner's mental compensation effect can improve psychological marginal compensation coefficient. In the actual case, positive psychological compensation role by active communication and coordination can reduce or even avoid conflict in the project.

The analysis of the contractor's expected utility

Bring each cross decision according to the conflict matrix from figure 3 into the owner's expected function $E_{V_2}(\sigma_1,\sigma_2)$, It could get several expected utilities by analyzing the contractor's different strategic choices.

When the contractor chose to cooperate, the expected utility is:

$$E_{V_{cooperate}}(\sigma_1,\sigma_2) = qV_2 + (1-q)(V_2 - Y_2 - h_2) \quad (10)$$

While the contractor chose non-cooperation, the expected utility is:

$$E_{V_{non-coo}}(\sigma_1,\sigma_2) = q(-V_2 - Y_2 + h_2) + (1-q)(-V_2 - Y_2) \quad (11)$$

And the average expected utility can get, that is:

$$E_{V_2}(\sigma_1,\sigma_2) = p[qV_2 + (1-q)(V_2 - Y_2 - h_2)] + (1-p)[q(-V_2 - Y_2 + h_2) + (1-q)(-V_2 - Y_2)] = 2pV_2 + pqY_2 - ph_2 + qh_2 - Y_2 - V_2 = (2p-1)V_2 - (1-pq)Y_2 + (q-p)h_2 \quad (12)$$

Similarly, $E_{V_2}(\sigma_1,\sigma_2) \geq -V_2 - Y_2 - h_2$

To derivative for objective function, then,

$$\frac{\vartheta E_{v2}}{\vartheta p} = 2V_2 + qY_2 - h_2$$

The first order condition, $q^* = -\frac{2V_2}{Y_2} + \frac{h_2}{Y_2}$ (13)

It can draw the conclusion according to participation constraint (IR) in conflict management, $\max_p(2pV_2 + pqY_2 + qh_2 - ph_2 + h_2)$

When $q > -\frac{2V_2}{Y_2} + \frac{h_2}{Y_2}$, the contractor may choose to cooperate strategy;

If $q < -\frac{2V_2}{Y_2} + \frac{h_2}{Y_2}$, the contractor may choose non-cooperation behavior;

While $q = -\frac{2V_2}{Y_2} + \frac{h_2}{Y_2}$, the contractor may choose mixed strategy.

It can find that overall expect of both the owner and the contractor can achieve the optimal if $p = q$ by analyzing both of their excepted utilities, that is, in the mixed game, the owner chooses affirmation behavior and the contractor chooses cooperation can maximize the total income.

Take $Y_2 = e_2 s_{conflict} = e_2\left(T'_{time} + C'_{cost} + Q'_{quality}\right)$ into q^*

$$q^* = \frac{h_2 - 2V_2}{Y_2} = \frac{-h_2 + 2V_2}{e_2\left(T'_{time} + C'_{cost} + Q'_{quality}\right)} = \frac{h_2}{-e_2\left(T'_{time} + C'_{cost} + Q'_{quality}\right)} + \frac{2V_2}{e_2\left(T'_{time} + C'_{cost} + Q'_{quality}\right)} \quad (14)$$

Similarly,

$a_2 = \frac{V_2}{-Y_2} = \frac{2V_2}{e_2\left(T'_{time} + C'_{cost} + Q'_{quality}\right)}$ is the contractor's revenue coefficient,

$\beta_2 = \frac{h_2}{Y_2} = \frac{h_2}{-e_2\left(T'_{time} + C'_{cost} + Q'_{quality}\right)}$ is the contractor's coefficient of mental compensation effect.

(1) The contractor trend to choose collaborative behavior and cooperation is preferred strategy in solving conflict problems if the contractor's opportunity revenue and income coefficient are increase.

(2) Some factors such as quality, time and cost out of control will result in the contractor's non-cooperation behavior. Therefore, Withdrawing is the contractor's preference strategy.

(3) The contractor will prefer the retreat strategic, because their earnings and income coefficient will reduce if they choose to negotiate with the owner in order to avoid losses. At the same time, the contractor's efforts to avoid losses will improve mental compensation coefficient and promote the owner choose affirmation behavior while they choose accommodate strategy in the game of conflict.

(4) The contractor's efforts for their interests will induce the generation of new conflicts. If previous conflict is not well resolved, the contractor's psychological effect of making compromise to the owner may induce potential conflicts.

(5) The contractor's mental compensation effect may improve their psychological marginal utility compensation coefficient, the owner's choice of certain behavior will promote the contractor choose cooperative strategy. On the contrary, the less psychological compensation utility the contractor gain while trying to get more profits from the owner, the less willing to cooperate with the owner.

According to comprehensive analysis of the owner's and the contractor's expected utility, rational economic people will make decision by comparing with different marginal utility based on the theory of Pareto optimality. It can get the formula:

$$p^* = 2a - \beta \quad (15)$$

According to analysis, it shows that 'p^*' and 'a' is positive correlation. With increasing of revenue coefficient, the owner prefers affirmation strategy and the contractor prefers cooperation with the owner. While the 'p^*' and 'β' is negative correlation, with the owner's mental compensation coefficient obtained by making compromise with contractor increasing, the owner will more to choose the retreat strategy to the contractor's claim in the project.

Evolutionary Game Analysis of the Conflict

In the process of limited rational static game, it has been proved that the initial conflict could avoid by sufficient mental compensation effect. However, both sides should find the evolutionary stable equilibrium to undergo the interference of error and deviation caused by

limited rational game in conflict management, so exploring many times repeated game between the owner and contractor can simulate the dynamic game of conflict [22].

If conflict occurs is continuous, it will lead to the overall process of dynamic adjustment of continuous time, namely the Replicator dynamic strategy. Replicator dynamic strategy is a kind of complete strategy, $S_i = \{s_{i1}, s_{i2}, \dots, s_{ik}\}$. With replication group state changing, the income from different complete strategy S_i will change either [23].

Assumed group breeding for the conflict frequency, Replicator dynamic strategy represents the strategic choice of the initial conflict game between both sides, then the owner's Replicator dynamic equation can represent:

$$F(q) = \frac{dq}{dt} = q[E_{V_{affirm}}(\sigma_1, \sigma_2) - E_{V_1}(\sigma_1, \sigma_2)] = q(1-q)(2V_1 + pY_1 - h_1) \quad (16)$$

Order $\frac{dq}{dt} = 0$, $q^* = 0$, $q^* = 1$, $p^* = \frac{h_1 - 2V_1}{Y_1}$ (17)

According to stability of differential equations and evolutionary stable strategy,

When $F'(q^*) < 0$, q^* represent evolutionary stable strategy;

When $p^* = \frac{h_1 - 2V_1}{Y_1}$, $F(q)$ is always equal to zero, at this time the contractor's degree of cooperation reach to p^*(The initial probability of game), the owner's probability distributions is stable whatever affirming or negative.

If $p > p^*$, $F'(0) > 0$, $F'(1) < 0$, $p^* = 1$ is unique evolutionary stable strategy. The owner's affirming behavior and the contractor's cooperation strategy built a great interaction strategy, which can contribute to establishment of partner mode.

If $p < p^*$, $F'(0) < 0$, $F'(1) > 0$, $p^* = 0$ is unique evolutionary stable strategy. When the contractor is lack of awareness of cooperation, the degree of the owner's affirming will be gradually disappeared. With the intensification of the conflict, the owner won't support its partner step by step.

The contractor's Replicator dynamic equation is:

$$G(p) = \frac{dp}{dt} = p[E_{V_{cooperate}}(\sigma_1, \sigma_2) - E_{V_2}(\sigma_1, \sigma_2)] = p(1-p)(2V_2 + qY_2 - h_2) \quad (18)$$

Order $\frac{dp}{dt} = 0$, $p^* = 0$, $p^* = 1$, $q^* = \frac{h_2 - 2V_2}{Y_2}$ (19)

If $G'(p^*) < 0$, $p^*$is evolutionary stable strategy.

If $q^* = \frac{h_1 - 2V_1}{Y_1}$, $G(p)$ is always equal to zero, that is, the degree of the owner's affirming(disposable probability of the game) reach to q^*, the probability of the constructor's collaboration is stable.

When $q > q^*$, $G'(0) > 0$, $G'(1) < 0$, $q^* = 0$ is unique evolutionary stable strategy. The contractor's affirming behavior and the owner's cooperation strategy built a great interaction strategy.

If $q < q^*$, $G'(0) < 0$, $G'(1) > 0$, $q^* = 0$ is unique evolutionary stable strategy. It means that the contractor tend to non-cooperate strategy if the owner's certain degree is not enough or chooses affirming strategy. After several conflicts, the contractor is unwilling to cooperate with the owner ultimately.

Several conflicts later, considering the evolution of the owner and the contractor, revenue (V_1, V_2) and conflicting cost (Y_1, Y_2) will be main basis of their strategy for both of them, that is, the higher the cost of conflict and the higher revenue, the more severe of the conflict between them. The mental compensation effect (h_1, h_2) will not work gradually with the intensification of the conflict.

The following diagram is about the evolutionary Trends between the owner and contractor.

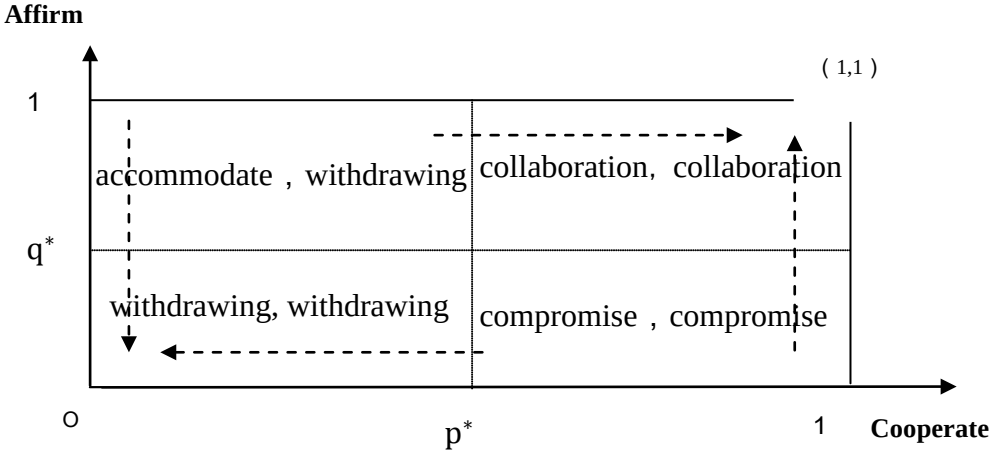

Figure 4. The phase diagram of conflict evolution game between the owner and the contractor

It can be known by the phase diagram of conflict evolution game between the owner and the contractor, (1,1) and (0,0) are the evolutionary stable strategy of conflict game(ESS), but which strategy will be converged eventually is still determined by initial conflict game results.

If the initial conflict game result is collaboration, ESS will converge to Pareto optimal equilibrium (1,1), that is, the owner chooses affirming behavior and the contractor chooses cooperation strategy.

When the initial conflict game result is withdrawing, ESS will converge to Pareto worst equilibrium (0, 0), that is, the owner chooses affirming behavior and the contractor chooses non-cooperation strategy.

If the initial conflict game result is compromising or accommodating, the direction of conflict evolutionary game is uncertain. The result either it is likely converge to collaboration with each other (1,1), or may converge to withdrawing (0,0) because of their retreatment, so the state (1,0) and (0,1) are unstable state.

p^* and q^* are the critical value in the conflict evolutionary game, if the initial conflict game result is close to the threshold, the tiny change of initial conflict game will directly affect the final result of repeated game. It reflects the evolutionary game is sensitive to initial game, which is the result of the initial conflict game has a significant influence on the result of the conflict game.

In the initial conflict game, the thresholds are $p^*_{initial}$ and $q^*_{initial}$:

$$p^*_{initial} = \frac{-h_1+2V_1}{e_1(T_{time}+C_{cost}+Q_{quality})} \quad (20)$$

$$q^*_{initial} = \frac{-h_2+2V_2}{e_2(T'_{time}+C'_{cost}+Q'_{quality})} \quad (21)$$

It can be obtained by comparing these thresholds in the evolutionary game, the cost of conflict will increase with the increase of T_{time}, C_{cost} and $Q_{quality}$, and the mental compensation effect will gradually decrease along with the increasing the number of game. The main factors influencing the evolution game decision-making is the benefits of all parties and conflict cost if the mental compensation effect is insufficient.

Conclusion

It can be achieved the ESS of both sides in the progress of several conflict games, by building a model of complete information static game to simulate conflict game in construction project and to analysis the evolutionary game, which has provided the basis for both sides to manage the goal conflict.

In the initial conflict game, Opportunity benefits, conflict costs and mental compensation effect are three main factors to both of their decision how to take actions to deal with the conflict.

The larger benefit coefficient, the more harmony for both sides would be, collaborative strategy is a better way to deal with the conflict for both sides. Meanwhile, mutual efforts for cooperation have reduced the benefit coefficient and reduce profits, the owner chooses accommodating strategy and the contractor have chosen withdrawing easily accordingly.

There are lots of elements causing high conflicting cost, such as bad quality, schedule time and building cost. The priority strategy are making compromise for the owner and withdrawing for the contractor.

The mental compensation effect of both sides may promote the marginal coefficient mental compensation effect. On the contrary, the less psychological compensation one party gets for their respective interests, the less willing to cooperate with the other positive effect one. Especially, short-term active communication and coordination can bring positive effects to reduce or even avoid conflicts. Meanwhile, mental compensation utility may diminish gradually along with the increasing of conflict game, when the mental compensation effect is not high enough, revenue and conflicting cost would be the main impacts on their decisions.

After several repeated gaming between the owner and the contractor, mutual collaboration and withdrawing are the evolutionary stable strategy of conflict game(ESS). If the initial the result of conflict game is cooperation, ESS has converged to Pareto optimal equilibrium, if the initial the result of conflicting game is withdrawing, ESS has converged to Pareto worst equilibrium.

The changed direction of evolutionary game is uncertain, if the initial result of conflict game is that the owner chooses accommodating behavior and the contractor chooses compromising or withdrawing strategy. However, both sides have converged to mutual collaboration or withdrawing ultimately. Therefore, the tiny change has affected the last conflict strategy after rounds of contests, when the initial game is close to the threshold.

Acknowledgements

This work was supported by Jiangxi province special fund of visiting scholar program for young and middle-aged teachers development

plans in ordinary undergraduate course colleges and universities.

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