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Application of Game Theory Approach in Solving the Construction Project Conflicts

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Abstract

Nowadays, conflicts between the involved parties in projects are common. So a useful decision making method should be considered for a better decision. Game theory approach can be used as an efficient framework in decision making about some problems and conflicts in construction projects. The aim of this paper is to find the best outcome in conflicts for every player (party) according to his opponents' decision. Two game theory structures have been discussed here, Prisoners' Dilemma and Chicken Game. Two types of probabilistic conflicts during the construction project have been discussed based on these two games and the results highlight the applicability of the game theory application in construction projects' dispute resolving. The study also is resulted that application of the chicken game and prisoners' dilemma game is so helpful for analyzing construction management problems.

Keywords: Chicken Game; Construction management; Game Theory; Prisoners' dilemma;

1. Introduction

Managing construction projects usually involves some conflicts which may occur among the stakeholders, main contractors and/or among main contractors and sub-contractors. However, achieving a win-win situation is the most desirable one for every player, but sometimes, players' decisions lead to the worse and critical conditions for all involved parties in the construction projects. These conflicts can occur during the executing of the project because any parties involved in the project may act on behalf of themselves whereas in game theory approach benefits of whole parties are considered.

Game theory can recognize and clarify the behaviors of parties involved in the project to construction project problems and describe how interactions of different parties such as stakeholders (client), main contractors or subcontractors can lead to project evolving. The game theory and optimization methods results are often different

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because in optimization methods all parties are willing to act in which can lead to the best results for the whole system, while in the game theory each party tend to act in which can lead to the most logical outcome for him that may not be the best result for the whole of the system. This study surveys suitability of game theory to construction project Structure management and conflicts solutions through a series of non-cooperative construction project contract games. The paper illustrates some contractual structure of construction project problems and consequences of considering the game's evolution path while investigating such problems. And it shows the usefulness of game theory approach in construction projects and conflicts resolutions related to them by discussing the basic concepts of game theory and demonstrating some simple construction project conflicts by using some kind of game theory approach such as prisoner's Dilemma and chicken game.

2. Literature review

The existed conflicts in construction issues not only limited to the sharing of expenses or profits between main contractors and sub contractors, but also, sometimes there are conflicts driven from clients and main contractors due to the non-cooperative behaviors between them. These conflicts may be driven from different issues such as project delays or suspension, differing site conditions, contract changes and etc. If these conflicts not peacefully be resolved, they can lead to non compensable consequences, such as project suspension that can cause considerable lost for both parties involved in the project. In this situation the best decision should be considered for resolving the conflicts.

Different quantitative and qualitative methods have been proposed for conflict resolution in water resource management, and some of them have been mentioned in Madani (2010):
Interactive Computer-Assisted Negotiation Support system (ICANS) (Thiessen and Loucks, 1992; Thiessen et al., 1998), Graph Model for Conflict Resolution (GMCR) (Hipel et al., 1997), Shared Vision Modeling (Lund and Palmer, 1997), Adjusted Winner (AW) mechanism (Massoud, 2000), Alternative Dispute Resolution (ADR) (Wolf, 2000), Multivariate Analysis Biplot (Losa et al., 2001), and Fuzzy Cognitive Maps (Giordano et al., 2005). Wolf (2002) presents some significant papers and case studies on the prevention and resolution of conflict (using descriptive methods) over water resources.

Von Neumann and Morgenstern (1944) introduced basic concepts of cooperative game theory and Shapley (1953) introduced the Shapley value as a cooperative game in order to used as a cost and benefits allocation in a coalition. Fuzzy coalition was firstly proposed by Aubin (1974), "In his definition, fuzzy coalition is an n-dimensional vector which its components are membership degree of players in the coalition" (Sadegh et al., 2009).

One of the most efficient tools to investigate these issues is game theory. In the construction management different decision-makers are involved at various stages such as design, construction, operation, utilization and maintenance, due to that the use of game theory is required in the definition and interpretation of the behavior of different parties involved the system. The most common issue in every project is that all involved parties prefer their own profits to overall system profits. Due to that the results obtained from game theory approach are different from results of traditional optimization method. Game theory provides a framework for evaluating the effects of individual decision makers' actions on the result of the projects to develop satisfactory resolution more extensively. However game theory has not been used well in construction projects yet. Thus it is still unclear for all parties involved in the construction projects owing to lack of knowledge and understanding its basic concept. Game theory will become so interesting in construction industry to realize and resolve some construction projects conflicts which might not logically be solved by conventional system engineering methods. In general game theory's results are more logical and closer to practice since this method can better reflect behaviors of the parties involved in the project.

This paper illustrates the usefulness of game theory approach in construction projects and conflicts resolutions related to them by discussing the basic concepts of game theory and demonstrating some simple construction project games.

3. Methodology

This paper has studied the application and the applicability of the Game theory approach in solving construction management problems. Two game theory structures have been discussed here, first of all, prisoners' dilemma. The prisoner's Dilemma game was first proposed by Merill Flood (1951). In this game two suspects are captured by the police. The police suspect that they are in charge of a crime, but do not have adequate evidence to prove it in court. For shriving from criminals, police put them in separate cells without any communication to each other. And, so on…. The second game is: chicken game, and that is, imagine two young drivers are driving two fast cars toward each other in a narrow road. The probability of death for both young drivers is high, if none of them turn his direction. The priorities of these two drivers in this game are that they will not play the timid role. So the best payoff is to have your opponent be the chicken. Two problems have been discussed based on this two games and the results emphasis the applicability of the game theory application in construction management field.

4. What is game theory?

Game Theory was firstly explored by a French mathematician named Borel in 1921. Emile Borel published several papers on the theory of games. He used poker as an example and addressed the problem of second-guessing the opponent in a game. He imagined using game theory in economic and military applications and his goal was to determine, whether a best strategy for a given game exists and find that strategy. However, he did not develop his idea very far. Due to that, most historians give the credit for improving game theory to John Von Neuman(1903), who published his first paper on game theory in 1928, seven years after Borel.

Game theory is a method originated from the mathematical sciences in which is used in competitive or cooperative position to find optimal choices that will lead to desired outcome. In every game at least two players will be involved in who will gait to maximize their own benefits with regard to opponent's decision. In fact, it is becoming popular and interesting in some fields such as economics, sociology, political and management sciences. In the mentioned fields game theory can be used to anticipate the best result.

May be the main characteristics of game theory is measurement and evaluation of opponent's reaction in the game and achieving to a belief than the opponent's choice and deciding according to that belief. In a game, players according to their beliefs about the opponent's choices choose a strategy or strategies that will maximize profit for them. Game theory says that whenever people are playing with each other in the strategic environment, how they behave rationally. Thus this approach can cause the rational and best results for the player.

Game theory has different extension and it is categorized into different classification such as dynamic and static game, zero-sum and non-zero-sum game and etc. In dynamic games players make decision in response to other players' decisions while in static games, all players' choice are decided simultaneity.

A zero-sum game is one in which no wealth is created or destroyed. So, in a two-player zero-sum game, whatever one player wins, the other loses. The theory of zero-sum games is immensely different from that of non-zero-sum games, because an optimal solution can always be found. Most of the games in the real life are non-zero-sum games. All players may lose or win in this kind of games and cooperation of players in this type of games can lead to win-win situation for all players. Most of the construction management issues are also the non-zero-sum games in which the collaboration of involved parties (players) can achieve the better result for the system. The typical non-zero-sum games are Prisoner's Dilemma, chicken and Volunteer's Dilemma and Deadlock and stag hunt. This paper is going to investigate and model some construction issues and conflicts in these kinds of non-sum-zero games between client and main-contractor and between main-contractors and sub-contractor to specify and clarify the best solution for them (players) and whole system.

4.1. The prisoner's dilemma

The prisoner's Dilemma game was first proposed by Merill Flood (1951). In this game two suspects are captured by the police. The police suspect that they are in charge of a crime, but do not have adequate evidence to prove it in court. For shriving from criminals, police put them in separate cells without any communication to each other. If neither prisoner confesses, both will be convicted of about one year. If both confess to their crime then both will be sentenced to 5 years. If however, one prisoner confesses to his crime, while the other does not, then the prisoner who confessed will be forgiven while the prisoner who did not confess will be convicted to 10 years. In this stage the question which exists in the criminals' mind is that which decision can be the best for each of them against the opponent's decision. For answering to this question it is better to use game theory approach and Nash equilibrium solution. For implementing this game in the framework of game theory, firstly, the game should be written in matrix form. The value in each cell shows the time spent in prison.

Table 1. Strategies which can be used for prisoner's Dilemma game

Strategies which can be used for prisoner's Dilemma game		Player 2 (Criminal 2)	
		Confess	Deny
Player 1 (Criminal 1)	Confess	(5, 5)	(0, 10)
	Deny	(10, 0)	(1, 1)

With regard to the above matrix, each prisoner is looking to minimize his prison time. Since the criminal 1 and/or player 1 does not know whether his partner in crime has confessed or not, first he assumes that he has not. If prisoner 1 does not confess either then both will go to the prison for 1 year. this is good for them. But, if prisoner 1 confesses, he will go free, while his partner goes to prison. Now consider the other possibility that Prisoner 2 confesses. In this situation if prisoner 1 does not confess, he will go to prison for 10 years. But if he does confess, he will be in prison for 5 years. In this case it is obviously better to confess. According to the matrix, it is obvious that the best payoff for the both prisoners is when neither confesses. But game theory says that it is better for both to confess, since this situation is a non-cooperative form, so the player cannot rely on the other player.

As is understood from the results of the game, players in the game should choose a decision to find the best outcome according to the opponent's decision while this decision may not lead to the best outcome of the system. In general, it must be said that the Nash equilibrium point is not necessarily coincide with the Pareto optimal point.

Table 2. Strategies which can be used for prisoner's Dilemma game and the Nash equilibrium point

Strategies which can be used for prisoner's Dilemma game and the Nash equilibrium point ,and choosing the confessing strategy by both players		Player 2	
		Confess	Deny
Player 1	Confess	(5, 5)	(0, 10)
	Deny	(10, 0)	(1, 1)

According to the table above, there are three Pareto optimal points in the prisoner's Dilemma game, which are 1. (Confess, Deny) - 2. (Deny, confess)- 3. (Deny, Deny). But the choice of the players is the point except for the Pareto optimal points. Players in prisoner's Dilemma non-cooperative game will choose the Nash equilibrium that is (Confess, confess). (Confess, confess) strategy is the one that will minimize the win chance of opponent.

4.1.1. Application of prisoner's dilemma game in resolving the probabilistic conflicts during the construction

Practical example:

Imagine a big project has been divided into two phases, faze1&faze2. The main contractor handed over these phases to sub-contractor1 and sub-contractor2. During the executing of these two phases by these sub-contractors, some infrastructure works such as drainage, sewerage and slope protection must be executed for these phases. Due to lack of space and time and much more additional cost, it is more beneficial for the main-contractor to contract with these sub-contractors instead of contracting with the third (new) sub-contractor. So with regard to this situation, main-contractor bids a price to sub-contractor 1&2 for implementation of these infrastructure works. Here a question for each of the sub-contractors that will happen is that what each of them should decide to make the best decision against the other sub-contractor. The answer can be found with the help of prisoner's Dilemma game theory and the Nash solution. For implementing this game in the framework of game theory, first it should be written in the matrix form.

Table3: Strategies which can be used in prisoner's Dilemma game for sub-contractor 1&2

Strategies which can be used in prisoner's Dilemma game for sub-contractor 1&2		Player 2 (and/or Sub-contractor 2)	
		Accepting doing the infrastructure works	Denying doing the infrastructure works
Player 1 (and/or Sub-contractor1)	Accepting doing the infrastructure works	(P1,P2)	(P3,0)
(P4,P4)	(0,P3)	Denying doing the infrastructure works	

$$P1= P2, \quad P3= P1+P2 \quad , P4 > P1 \& P2, P3 > P4$$

Assuming there is not any communication between the both of sub-contractors. In fact, it is a non-cooperative game which both sub-contractor 1&2 do not know about each other's strategy and each of them wants to get more profit with regard to his opponent's strategy. In the above matrix, there are 4 situations. Now, we discuss each 4 situation for both sub-contractors.

Situation 1: [sub-con1 (accepting), sub-con2 (accepting)]: The achieved benefits by this situation are (P1, P2) for sub-contractor1&2 that P1= P2. In this strategy, benefits are divided between both sub-contractors and each of them makes profit from that.

Situation 2: [sub-con1 (accepting), sub-con2 (denying)]: The benefit achieved in this situation is (P3, 0). In this strategy all of the benefit is achieved by sub-contractor1.

Situation 3: [sub-con1 (denying), sub-con2 (accepting)]: The benefit achieved in this situation is (P3, 0). In this strategy all of the benefit is achieved by sub-contractor2.

Situation 4: [sub-con1 (denying), sub-con2 (denying)]: In this situation both of the sub-contractors think that if they do not accept the main-contractor's bid then the main-contractor has to increase the bid price. Then both sub-contractors can make more profit. In fact this strategy can be used when both sub-contractors to be aware of each other's strategy. Then the benefit achieved by subcontractors is P4 that P4>P1&P2 and P3>P4. But in this situation, there would be no guarantee that any of the ones will not infract the agreement.

As mentioned before, according to the prisoner's Dilemma game there are three Pareto optimal points in this game which are (accepting, denying), (denying, accepting) and (denying, denying). But the Nash equilibrium point is (accepting, accepting) that is the best strategy which can be achieved the most profit for each of sub-contractors with considering their opponent's strategy. So the ideal strategy according to the game theory is (accepting, accepting).

4.2. Chicken game

The other interesting game which can be used in construction management is chicken game. In this game, imagine two young drivers are driving by two fast cars toward each other in a narrow road. The probability of death for both young drivers is high, if none of them turn his direction. The priorities of these two drivers in this game are that they will not play the timid role. So the best payoff is to have your opponent be the chicken. The worst possible payoff is to crash to each other. So in the matrix for this game, this situation has the least value. We assign it 1. As mentioned before, the best payoff for each driver is to have his opponent be the chicken, so we assign it a value 4. The next worst possibility is to be the chicken, so we assign this a value 2. The last possibility is that both drivers swerve at the same time. We assign this a value 3. In this strategy they can maintain their pride and life, so this is preferable to being the chicken. But in these circumstances none of the players neither will be a loser nor will be a winner.

Table 4: Strategies which can be used for chicken game

<table>
<tr><th colspan="2">Player 2 (Driver2)</th><th colspan="2" rowspan="2">Strategies which can be used for chicken game</th></tr>
<tr><th>Do not swerve</th><th>Swerve</th></tr>
<tr><td>(2, 4)</td><td>(3, 3)</td><td>Swerve</td><td rowspan="2">Player 1 (Driver1)</td></tr>
<tr><td>(1, 1)</td><td>(4, 2)</td><td>Do not swerve</td></tr>
</table>

According to the matrix above, the game has two Nash equilibrium points that are (swerve, do not swerve) and (do not swerve, swerve). In addition being the Nash equilibrium, these two options can be also Pareto optimal points. There is also another optimal Pareto point that is (swerve, swerve). At this point, both players reach to equality state and the play will have no loser or winner.

4.2.1. Application of chicken game in resolving the probabilistic conflicts during the construction

Many factors can affect the finishing of the project on time. One of them is delaying on delivery of material on site which will cause a delay the project. Assuming in a project, 70 percent of work has been implemented. At this time, unavailability of some materials in the market causes an interruption in the project. On the other hand, this activity is in critical path according to the work schedule which every interruption on that can directly affect the project completion date and will lead to the delay. In this situation, the dispute arises between client and contractor, since on the one hand, the client discerns this delay as a non-excusable delay which due to the contractor's fault but on the other hand the contractor tries to justify this situation to change the delay to excusable delay for getting the additional time from the client. In this situation, the contractor has two ways or strategies:

1. Taking the short-term corrective action such as work over time

2. Does not take any short-term corrective action and continue the project implementation with the previous speed.

Chicken game is one kind of game theory for modelling the situation of this conflict between contractor and client. For modelling this game in the framework of game theory, first it must be written in the matrix form.

Table 5. Strategies which can be used by client & contractor in chicken game theory

Player 2 (contractor)		Strategies which can be used by client & contractor in chicken game theory	
Non over time work (fixed speed)	Over time work (increase mobility)		
(2, 4)	(3, 3)	Gives extension time	Player 1 (client)
(1, 1)	(4, 2)	Gives no extension time	

The numbers shown in the matrix above are qualitative and they determine just the desirability of the outcome than the others. The situation [Client (gives no extension time), contractor (non over time work)] can lead to the worse status that may cause the project suspension. This game has two Nash equilibrium points, (no extension time, overtime work) and (extension time, non overtime work). This means that eventually, one of the players (client or contractor) should compromise to help in continuing of the project.

5. Conclusion

Facing conflicts in construction managing problems due to the different involved decision makers are unavoidable. And so, analyzing this kind of problems is so different compare to the single decision maker ones. In single decision maker problems most of the analysis is taking a place using the traditional optimization and/or simulation methods. However, using these mentioned traditional optimization simulation methods are still effective for multi-decision maker problems but, they are not enough for a proper analysis. Therefore, using other methods such as game theory approach would be so helpful for multi-decision maker problem analysis. In this study, we tried to analyze and model two problems in constructing management using game theory approach. Firstly, we define a problem in which two different decision makers as two sub-contractors of a big project should are involved in. In this problem, each of these two sub-contractor should analyze and predict the other one's decision in offering a proper suggest in accepting or denying an offer from the upper contractor. This game is analyzed using prison dilemma structure. The result emphasizes the applicability of the prisons dilemma game structure in analyzing such a problem. The other interesting game which has been used here is chicken game. We analyzed the other constructing management problem, using chicken game which is a conflict between two decision makers. One of these two decision makers is a client and the other is a contractor. The application of the chicken game is so helpful for analyzing this game. Therefore, it can be said that using game theory approach is so helpful for analyzing construction management problems. And for more research we can focus on the dynamic game in constructing management cost problems.

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