The Application of Game Theory in Engineering Project Management

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Abstract: The coexistence of conflict of interest and cooperation are two of the most significant characteristics in the process of construction project management. To maximize their interests, all parties involve and restrict each other in the process of management, resulting in the phenomenon of information asymmetry between Party A and Party B, passive slacking of contractors, project quality defects, and project claims in the process of project management. By applying game theory to the construction of engineering projects, it can facilitate managers from all parties to choose better decisions, thereby further improving the level of engineering management and expanding their own profits. Starting from the basic concepts of game theory and engineering project management, this article focuses on three perspectives: project bidding stage, construction stage, and engineering claim stage. It analyzes the game between owners and contractors under incomplete information conditions and concludes that both parties should realize the sharing of information resources and strictly abide by the principle of engineering contract equality. Several suggestions related to engineering project management are also proposed.

Keywords: Game theory, project management, project bidding, engineering construction, engineering claims

1. Introduction

Project management is a branch of management that refers to the process of applying specialized knowledge, skills, tools, and methods in project activities to enable projects to achieve or exceed set requirements and expectations within limited resource constraints. Early project management focused on program control techniques and organizational structures, but recent developments in project management have placed a strong focus on the role of "people" in project management. Nowadays, project management is playing an increasingly important role in many fields.

Engineering project management refers to the enterprise engaged in engineering project management, entrusted by the owner of the project, to carry out professional management and service activities in the whole process or stages of engineering construction. The main content of engineering project management can be divided into the project management of the owner, the project management of the general contracting unit of engineering construction, the project management of the design unit, and the project management of the construction unit. Some unpredictable risks during project implementation may cause some problems in the construction project management process to a certain extent, for example, information asymmetry among all parties involved in construction

project management; the level of construction project management contracts is relatively low; and the lack of reasonable supervision in construction project management. To improve the efficiency and quality of the overall construction project, all parties in the construction industry must strengthen the application management of the construction project to ensure that the project management can be strictly implemented in every stage of the construction project. Good engineering project management can greatly enhance the market competitiveness of enterprises. Specifically, for a certain project, scientific and systematic management can significantly improve the project from the early bidding stage to the construction stage [1].

Game theory refers to the theory that participants, in situations of competition, cooperation, conflict, etc., fully understand the information of all parties and sequentially choose the optimal strategy that can strive for the maximum benefit for their side. The basic elements of game theory include: player in the game: in a competition or game, each participant with decision-making power becomes a player in the game. Strategy: refers to the collection of means and strategies possessed by players to deal with other players in the game. Profit vector: refers to the gains and losses of players in each game after a game. Usually, positive numbers represent the wins of players in the game, while negative numbers represent the losses of players in the game. Because game theory can deeply explore the essence of various management phenomena and study the complex subject behavior in engineering project construction from a unique perspective and thinking, it can play a crucial role in analyzing engineering project management. The research objective of this article is to apply game theory rules to analyze the behavior of owners and contractors in engineering project management, so that both parties can actively analyze each other's decision-making behavior in the early stage of construction enterprise selection, the later stage of construction, and the engineering claim stage, and achieve a more profound analysis of each other's decision-making behavior, to know oneself and the other as much as possible, thereby improving the overall efficiency and quality of the project, maximizing one's interests, and obtaining their ideal results.

2. The Application of Game Theory in the Bidding Stage

In the bidding process of construction projects, the interests and goals of the owner and the contractor are mutually opposed, but the owner has an information advantage and is in a relatively proactive position. All requirements and information for construction projects are controlled by the owner, while the contractor can only obtain partial information through bidding documents and on-site inspections [2]. The benefits of the contractor are not significantly improved due to this information asymmetry, which makes the game between the owner and the contractor more intense [3]. The goal of the owner is to complete the project at the lowest price while ensuring the quality and progress of the project; The contractor's goal is usually to win the project contract without affecting the contract between both parties and maximize their profits [4]. At this stage, the contractor does not know much about the owner's detailed construction intention and financial ability to pay and is most concerned about how to win the bid, the first thing to do is to take over the project first, as for the cost of being profitable, the quality of the project will be considered when constructing. The inconsistency of the two sides in the direction of the goal leads to the difference in the game mentality [5].

Therefore, both the owner and the contractor engage in a game without fully understanding each other's information, and can only rely on their actions to make decisions based on the information collected by the other party. So both owners and contractors should try to learn as much as possible about each other and other information about the construction market. Under normal circumstances, the lower the bidder's offer, the greater the chance of winning the bid, but the smaller the income after winning the bid; the higher the bidder's offer, the greater the income after winning the bid, but the smaller the chance of winning the bid, so the bidder must take into account the opportunity to win the bid and the income when bidding for the price. Owners usually set a set of evaluation criteria to screen

contractors, and contractors need to fully understand and analyze these evaluation criteria, consider their costs, risk tolerance, and market competition situation, and develop bidding strategies that are suitable for themselves and competitive [6].

3. The Application of Game Theory in the Construction Stage

After determining the contractor through the bidding process, the project enters the construction stage, during which the contractor is in an information advantage. The contractor has inherent advantages in controlling the authenticity of project construction information, with priority given to project payments and profits, especially when the main building materials are supplied by the contractor. Such behaviors as rough and shoddy construction and cutting corners increase the quality risk for the owner. Project quality is an important part of construction project management, and it is also the key to determining the success or failure of the project [7]. Usually, the owner's practice is to hire a supervision company to supervise, but there is also a possibility that it can be deceived by the collusion between the contractor and the supervision company [8]. Therefore, in practice, the owner usually relies on the allocation of project funds to restrain the contractor, and the owner's default on the project payment will lead to the contractor's passive sabotage and fall into the "prisoner's dilemma".

Table 1: Matrix of benefits for the owner and the contractor under different decisions

		Contractor	
		Active construction	Passive slacking
Owner	Timely payment	(-1，-1)	(-5，0)
	Delayed payment for work	(0，-5)	(-3，-3)

As can be seen from Table 1, (Delayed payment for work and passive slacking) is the Nash equilibrium of the matrix, but the optimal solution is (Timely payment and active construction). If there is no binding agreement between the owner and the contractor, both parties will fall into a "prisoner's dilemma", which is not an ideal outcome for both parties, therefore, the two sides should strengthen cooperation, formulate detailed and complete contracts, strictly follow the contract execution, and strengthen contract management to better achieve win-win results.

4. The Application of Game Theory in the Engineering Claim Stage

In the entire engineering project, due to the large differences in construction stages, long construction periods, and complex structures, there are usually some uncertainty factors within the project, which leads to frequent occurrences of claims. In this stage, the contractor hopes to obtain the maximum claim amount, but the owner can offset the loss from the project payment or performance bond payable to the contractor, which has a certain binding effect on the contractor. Therefore, the owner is in an information advantage [9]. When a claim event occurs, the claimant should fully consider the reasons for the claim, determine whether it was caused by the other party, draft a claim document based on the claim, and file a claim with the claimant [10]. When the claimed party receives the claim document, analyzes it to determine whether it is caused by its reasons. If so, claim the claiming party; if not, reject the claim made by the claimant.

If the owner and the contractor cannot reach a consensus on the current claim benefits, they will enter the mediation and arbitration stage. Let's assume that both parties pay arbitration fees of C, the

contractor is the claimant, the income of the election of mediation is Pt, the income of the successful claim of the arbitration is Pzs-C, and the income of the claim failure is Pzf-C; the owner is the counterclaimant, and if mediation is chosen, the income is -P-t; if arbitration is chosen, the income from successful claim is -Pzf-C; and if contractor's counterclaim fails, the income is -Pzs-C. Among them, Pzs>Pt>Pzf>C. The income matrix is shown in Table 2.

Table 2: Matrix of benefits for the owner and the contractor under different decisions

		Owner	
		Mediation	Arbitration
Contractor	Mediation	(Pt,-P-t)	(Pzf,-Pzf-C)
	Arbitration	(Pzs-C,-Pzs)	(Pzs-C,-Pzs-C)or(Pzf-C,-Pzf-C)

As can be seen from Table 2, taking the contractor as an example, when the contractor chooses mediation and the owner also chooses mediation, the income is Pt; and if the contractor chooses arbitration and the owner chooses mediation, the income is Pzs-C. Since Pt>C, the contractor should choose arbitration than mediation. When the owner chooses arbitration and the contractor chooses mediation, the income is Pzf; and if the contractor chooses arbitration, the income will be Pzs-C or Pzf-C, for the contractor, the income from successful claims is Pzs-C, and the income from failed claims is Pzf-C. As for the contractor, his expected value is higher, so he will consider obtaining the income Pzs-C. Since Pzs-C≥Pzf, the contractor should choose arbitration than mediation. So whether it is the contractor or the owner, their Nash equilibrium is (arbitration, arbitration), and the corresponding income combination is (Pzs-C, -Pzs-C) or (Pzf-C, -Pzf-C). Therefore, when the two parties can only resolve conflicts through mediation or arbitration, the contractor should pay attention to counterclaims, and the owner will also demand compensation from the contractor for the so-called "owner's interests". This requires the contractor to be familiar with and master the relevant contract terms and documents, comply with the claim procedure, pay attention to the timeliness of claims, accumulate sufficient and detailed claim evidence, calculate the claim amount reasonably, and avoid being in a passive situation [11].

5. Conclusion

This article analyzes the game between owners and contractors under incomplete information by examining the bidding stage, construction stage, and engineering claim stage in engineering project management. In the bidding stage, the owner should make the information sufficient, increase the degree of openness and transparency of the information, and the contractor should learn as much as possible about the project and formulate the best bidding strategy. During the construction stage, both the owner and the contractor should strictly adhere to the established contract, to avoid both parties falling into a "prisoner's dilemma" situation that is not good for each other, to achieve a win-win situation. During the engineering claim stage, the owner should establish an efficient management team and ensure that all indicators in the contract documents meet the requirements; the contractor should seize the excellent opportunity for claims and familiarize themselves with relevant contract documents to maximize their interests.

The owner should share information sharing with the contractor during the bidding stage. This can be achieved by establishing information-sharing standards, building information-sharing platforms, etc., to increase the transparency of information. By timely sharing information, the authenticity of information between both parties can be ensured, the efficiency and accuracy of the project can be improved, team collaboration can be promoted, and a win-win situation can be achieved.

The economic benefits of construction units are directly affected by the quality of contract management. Therefore, when drafting the engineering contract, Party A and Party B should focus on the overall perspective of the project, clarify the principles that must be followed in the contract management process, strictly review the details in the contract terms, promote the continuous improvement of the engineering contract management effect, and protect the rights and interests of Party A and Party B in the engineering construction.

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