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Article

Application of Game Theory to Conflict Management in a Construction Contract

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Abstract: Recently there has been growing interest in the application of game theory (GT) to solve many diverse problems in the field of construction, including i.a.: tender preparation, selection of a contractor for construction works, negotiating terms and conditions of cooperation of the parties to the contract, analysis and modeling of investment risk. In the authors opinion, the use of GT by general contractor (GC) of construction works to indicate the best strategy leading to winning court proceedings in a situation of conflict with investor (IN), so far has not been the subject of research. Taking into account the above, the aim of the presented paper is to indicate the optimal strategy from the GC point of view in the conflict situation with IN. The article presents a list of the most common causes of conflicts between parties of the construction works' contract, defines the background of the problem and the cause of the dispute, and on its basis, the authors generate the theoretical model of the game. Based on the analyzed game model, expected payoffs for players were calculated and the probability border value at which GC should apply the indicated strategy determined. The results of the study show that in the case when the probability of issuing a judgment favorable for GC is at least equal to 69.23%, it is justified to use an aggressive strategy. The analysis also confirms that from the financial perspective, litigation in most cases of conflicts in the area of construction should be the last choice.

Keywords: civil engineering; construction contract; court strategy; conflict modelling; decision analysis; game theory

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1. Introduction

In recent decades, there has been a lot of interest in the applications of game theory (GT) in science. In construction practice, games find application in modeling i.a. the following situations: tender preparation, selection of a contractor for construction works [1-4], entities cooperation [5], setting a portfolio of orders, building a market entry strategy for a new entity, product or service (technology), negotiating terms and conditions of cooperation of the parties to the contract [6,7], mediation between contractors, wage negotiations with employees, selection of the optimal technological variant [8,9], simulation of the course of conflict between entities competing in the same market, exploiting the same resource (e.g. employees, materials) [10-15], simulating the course of the "price war" between sellers of construction production, enforcing obligations of the parties to the contract [16], simulating the course of the conflict resolved in court, simulating the operation of the entity (development company, executive, warehouse of building materials) in a situation of high competition in the construction market [17-19], determining the level, scope and type

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of construction production depending on the market situation [20], identification, analysis and modeling of investment risk [21-24], management in the investment process [25,8,26,27,28,29] and optimization of investment projects [30-33].

Numerous reasons for conflicts between entities involved in the construction process can be identified [34-39] and categorized by the stage at which they occur, as follows:

1. During the preparation and submission of tender offers, the contractors are obliged to: verify the project documentation or the functional and operational program (FOP) to identify their defects, examine the area of planned construction in regard to provision of utilities and to geological and geotechnical conditions.
2. During project execution, after the contract is signed, the selected contractor is obliged to: remove the identified defects of the project documentation or the FOP, complete additional works.
3. During the final inspection the following causes of conflict can be identified: making the acceptance of works by the investor dependent on circumstances outside the contractor's control or unrelated to the construction process (e.g. delivery and launch of the production line by another supplier, service provider).

Made for the purposes of this article literature review indicates, that GT is widely used in solving many diverse problems in the field of construction. In the authors opinion, the use of game theory by GC of construction works to indicate the best strategy leading to winning court proceedings in a situation of conflict with IN, so far has not been the subject of research. Therefore, this approach to the problem is a novelty in the field of construction. The article presents a list of the most common causes of conflicts between parties of the construction works' contract, defines the background of the problem and the cause of the dispute, and on its basis, the authors generate the theoretical model of the game.

2. The cause of conflict between GC and IN – description and structure of the research problem

Due to serious defects of the project documentation supplied by IN, identified during works execution, the additional scope of works has been introduced. GC contacted IN to sign an annex to the contract, increasing the agreed lump-sum remuneration and extending deadline for the investment. IN rejected the claims of GC. Considering the consequences of available strategies at the stage of works execution GC decided to continue works. All works have been completed in accordance with the contract, as well as the additional works, resulting in an increase of cost and extension of the deadline in relation to the provisions of the contract. After investment completion IN applied contractual penalties for failing to meet the deadline and deduced this amount from the performance guarantee bond. GC referred the case to court demanding the return of contractual penalties withheld by IN, the cost of additional works and compensation for lost profits.

Both sides must select the strategy for the litigation and identify its consequences. To represent the game between GC and IN the following assumptions are made: value of the signed contract for construction works: 55 millions of monetary units, total time of investment completion: 500 workdays, value of the additional works completed by GC: 1.5 million of monetary units, amount of contractual penalties for failing to meet the deadline: 2.0 millions of monetary units, cost of profits lost: 2.0 millions of monetary units.

3. Game model proposition

The game has two conflicted players – GC and IN. It is analyzed from GC's perspective and aims to identify the best strategy for winning the litigation and maximizing the payoff. The analysis applies GT methodology. It is a game with imperfect information and two players [40].

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3.1. Assumptions for the constructed game model

The selection of strategy to be applied depends on the payoff and the player's expectations regarding the opponent's actions. The same decision space is assumed for both players. Two most probable strategies available to players are: aggressive or conciliatory.

1. The aggressive strategy means taking a decisive action and actively searching for the opponent's weaknesses. Its disadvantage is the considerable resources needed to prove the case in court (evidence e.g. numerous witnesses, expert opinions). It is assumed that the cost of long-term litigation is 2.6 million.
2. The conciliatory strategy means demonstrating readiness for dialogue and searching for rational compromise. The conciliatory strategy of the winning side results in smaller benefits than the aggressive one. Its advantage is significantly shorter litigation. It is assumed that the total cost of litigation is 0.5 million.
3. In case of adopting a mixed strategy (one of the players applies aggressive strategy, the other – conciliatory) the cost of litigation varies for both sides. It is assumed that for the aggressive player it will be 2.0 million, and for the conciliatory 1.0 million.

The decision space available results in four possible strategic combinations: two aggressive players (long and costly litigation), the conciliatory approach of both players (quick conflict resolution), two situations in which one of the sides assumes aggressive approach and the other is willing to compromise.

3.2. Game states

To define the payoffs for both players [3], the court ruling must be considered. The game is defined for two equally probable and separate states: 1. GC will certainly win, 2. the court will certainly rule in favor of IN.

For game states 1 and 2 payoff tables have been defined. The uncertainty of each game state is taken into account by assigning the probability value of a given state (for game state 1: probability equals 1.0, for game state 2: 0.0). At the current stage of the conflict the court ruling is unknown, therefore the next part of the paper considers two game states and assumes the same probability distribution of winning/losing the litigation by either side (Table 1, 2, 3). For game states 1 and 2, it is also assumed that the attitude of both players to court 'game' is the same.

3.3 Payoff tables for two game states

The calculation considers financial profits and losses dependent on the court ruling, the strategy applied by the player and cost of litigation. Those elements are considered for each of four possible combinations of strategies and two game states. It is assumed that the costs related to applying each strategy do not vary depending on the game state. Information presented in payoff tables (Table 1, 2, 3) are expressed in millions of monetary units.

Table 1. Litigation cost in millions considering each combination of strategy applied by players.

Player 1 - IN ➔ **Player 2 - GC ⬇**	**Aggressive strategy**	**Conciliatory strategy**
Aggressive strategy	(-2.6; -2.6)	(-2.0; -1.0)
Conciliatory strategy	(-1.0; -2.0)	(-0.5; -0.5)

3.1.1. Game state 1

If GC applies an aggressive strategy and wins, the payoff will be 5.5 million (2.0 million - contractual penalties deducted by IN, 1.5 million - the cost of additional works, 2.0. million - compensation for lost profits). IN will lose such amount (loss -5.5 million).

If GC applies conciliatory strategy and wins, the payoff will be 3.5 million (2.0 million - contractual penalties deducted by IN, 1.5 million - the cost of additional works). IN will lose this

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amount (loss -3.5 million) - see Table 2 for details (the calculations include the cost of litigation dependent on the selected strategy according to Table 1).

Table 2. Payoff table in millions of monetary units, if GC wins the court case.

Player 1 - IN ➔ **Player 2 - GC 🡻**	**Aggressive strategy**	**Conciliatory strategy**
Aggressive strategy	(2.9; -8.1)	(3.5; -6.5)
Conciliatory strategy	(2.5; -5.5)	(1.5; -2.5)

It is assumed that in the event of both sides applying the conciliatory strategy and GC winning, to resolve the conflict quickly, GC will agree to the reimbursement of only 2.0 million (contractual penalties). As a result, IN will lose this amount (loss -2.0 million). Nash equilibrium [4] exists for the case when GC applies aggressive strategy and IN conciliatory strategy to resolve the conflict. In such event, GC's payoff will be 3.5 million (profit), IN's – 6.5 million (loss).

3.1.2. Game state 2

If IN wins, GC will not get a refund of contractual penalties, incurring a loss (-2.0 million). IN will not gain 2.0 million, because earlier this amount was deducted from the GC's performance bond (see Table 3, this amount is not considered on IN's side). From IN's perspective, the game focuses on minimizing losses not maximizing profits.

In a conciliatory scenario, it is assumed that IN and GC agree to split the amount of 2.0 million (contractual penalties) evenly. GC receives 1.0 million and IN loses the same amount. Once again, the calculations include the cost of litigation depending on the dependent on the selected strategy according to Table 1.

Table 3. Payoff table in millions of monetary units, if IN wins the court case.

Player 1 - IN ➔ **Player 2 - GC 🡻**	**Aggressive strategy**	**Conciliatory strategy**
Aggressive strategy	(-4.6; -2.6)	(-4.0; -1.0)
Conciliatory strategy	(-3.0; -2.0)	(0.5; -1.5)

Nash equilibrium [41] exists if GC and IN apply conciliatory conflict resolution strategy. In such event GC's payoff will be 0.5 million (profit), IN – 1.5 million (loss).

3.4 Payoff analysis for two game states

Table 2 presents the game solution for game state 1, i.e. GC winning. It indicates that the best combination of strategies for GC (Nash equilibrium) is if GC applies an aggressive strategy and IN a conciliatory strategy. In such event, GC's payoff will be 3.5 million (profit), IN's – 6.5 million (loss). The result of the game indicates the dominant strategies for players.

Table 3 presents the game solution for game state 2, i.e. IN winning. The same payoff values for both players were applied, as for the game state 1. In this case, the players' payoff amounts, are different from game state 1. The best strategy for GC is also different.

In both game states players analyze applying clean (aggressive-aggressive, conciliatory-conciliatory) and mixed (aggressive-conciliatory, conciliatory-aggressive) strategies. From IN's perspective, for both game states, applying the conciliatory strategy is more beneficial as it IN's losses. It should be emphasized that in no combination of the game states and strategies, IN achieves positive payoffs. In game state 2 (IN wins), GC's payoff is positive (0.5 million) only in one case, IN's loss is then -1.5 million.

The game state has a significant impact on the players' payoffs. If the probability of GC winning the case is high - the best strategy for GC will be aggressive. However, if the ruling

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is in favor of IN, only with conciliatory strategy GC has a chance for the positive payoff (profit 0.5 million), otherwise, he will incur losses (negative payoff).

3.5 Expected payoffs for players for the new probability distribution

Based on the analysis of the existing rulings, for similar cases, it has been determined that they are not consistent and depend on the features of individual cases. Referring to the real conditions, the following probability distribution of two game states was arbitrarily adopted: 50% - ruling in GC's favor, 50% - in IN's. In this case, the payoffs are 2.0 million for GC (profit), - 4.0 million for IN (loss).

3.6 Border value of probability, model analysis, simulations

To select the right strategy for GC, the important information is the minimal (border) probability of favorable circumstances, at which an aggressive strategy (in game state 1) is beneficial. The probability border value can be calculated for each player. For GC it is calculated from formula (1) [3] [4].

$$p_1^* \bullet u_{GC11} + (1 - p_1^*) \bullet u_{GC12} \geq p_1^* \bullet u_{GC21} + (1 - p_1^*) \bullet u_{GC22} \quad (1)$$

where:

p_1^* - probability border value understood as the minimal probability of circumstances favorable for the contractor, in which it pays off to apply the aggressive strategy.

u_{GC11} - the payoff for GC when the aggressive strategy is used for game state 1,

u_{GC12} - the payoff for GC when the aggressive strategy is used for game state 2,

u_{GC21} - the payoff for GC when the conciliatory strategy is used for game state 1,

u_{GC22} - the payoff for GC when the conciliatory strategy is used for game state 2.

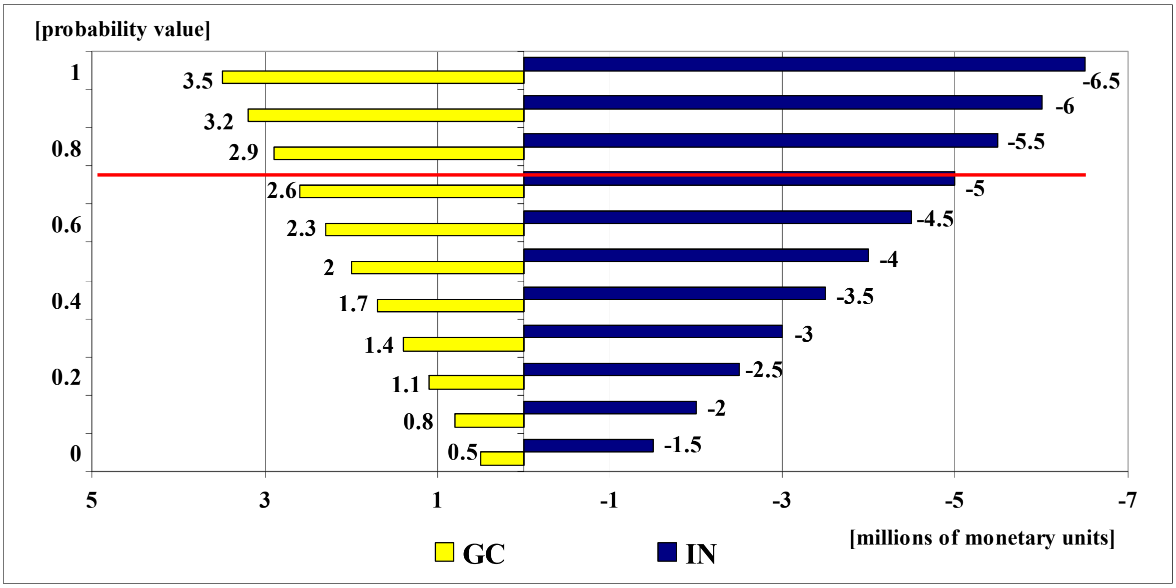

Figure 1. Simulation showing relation between expected payoffs for players (GC, IN) in millions of monetary units.

Figure 1 shows the relation between expected payoffs for players (GC, IN) in millions of monetary units. It can be observed, that to effectively apply aggressive strategy in court, GC must with at least 69.23% probability (Figure 1) know that the favorable circumstances will occur (numerous witnesses, hard evidence, expert opinions, passive and poorly prepared to the court case IN) and will have a decisive influence on the court's ruling. It can be also seen from the Figure 1, that the expected payoffs of both players depend on the changing probability value (from 1.0 to 0.0) of winning the court case by GC.

The extreme payoff values refer to game states 1 and 2, respectively. It is assumed that the strategies and decision spaces available remain unchanged, i.e. players still have the same optimal strategies in each game state. By changing the probability distribution of GC winning, the expected payoffs change. The simulation shows that as the likelihood of GC winning increases, the expected GC's payoff increases and IN's decreases (the loss increases). Figure 1 shows the expected payoffs for players depending on the probability value of the judgment in favor of GC.

4. Conclusions and recommendations

In this paper the optimal strategy for GC in a situation of conflict with IN has been analysed. Based on the analysis of the game model, expected payoffs for players have been calculated and the probability border value at which GC should apply the indicated strategy determined.

The calculated values of expected payoffs indicate the benefits of applying the available strategies by both players. Selecting the optimal strategy for GC depends on the predicted approach of the court. For GC in the first state of the game, the aggressive strategy is dominant, in the second state - the conciliatory. The conducted analysis has also shown that the main goal of the IN, in each combination of strategy and the two states of the game, is to limit the losses, not to gain a profit. For IN in both states of the game, the conciliatory strategy is dominant.

It should be emphasized that the two selected in the article - the main game states (win / loss of GC) are not the only payoff options for players. In practice, GC may, for example, win a case with a small compensation, be awarded a lower or total value of the claim. There is therefore a wide spectrum of decisions to consider, and the decision space is very complex. This issue is the subject of further research currently carried out by the authors.

The analysis has also confirmed that from the financial perspective, litigation in most cases of conflicts in the area of construction should be the last choice. Other - less expensive ways of resolving a conflict are an expert settling a dispute, an arbitration committee, or mediation.

In the light of the above, it should be emphasized that GT is a valuable tool supporting the decision process that can provide an advantage over the opponent, provided that the assumptions are correct and reflect the specifics of the situation. An important advantage of conflict modeling is the fact that decisions are based on rational premises and calculations.

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