Article

Application of Game Theory to Conflict Management in a Construction Contract

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Abstract: The subject of this article is the application of game theory (GT) to solve the problem occurring in the management of construction contracts. One of the fundamental reasons for disputes between the investor (IN) and the general contractor (GC) is payment for supplementary works – an additional expenditure incurred by GC that was not planned at the tender stage. If IN delays signing the annex to the contract and rejects any financial and timeframe-related claims, GC usually considers one of the two strategies: to stop works or to continue works without the annex and the guarantee of payment for additional works. IN also analyzes the consequences of adopting one of the two strategies: not to sign the annex, or to sign the annex and pay for the additional work. The aim of the presented game is to indicate the optimal strategy from the GC point of view in the conflict situation with IN. The article defines the background of the problem, the cause of the dispute, and formulates a theoretical model of the game.

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

1. Introduction – the main reasons for conflicts between the General Contractor (GC) and the Investor (IN)

In recent decades, there has been a lot of interest in and applications of game theory (GT) in science. Games describing situations from civil engineering area concern, among others, the following [1-13]:

- simulation of conflict between competing entities,
- simulation of entity's behavior (developer, construction company, construction materials wholesaler) in the situation of increased competition in the construction market e.g. price war,
- preparation of tender offer,
- negotiation of conditions and rules of cooperation between the parties to the contract,
- selection of the optimal technical solution.

Numerous reasons for conflicts between entities involved in the construction process can be identified [14-23] 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,

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- 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).

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.

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.

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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, 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 (Tab. 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 (Tab. 1, 2, 3) are expressed in millions of monetary units.

Table 1. Litigation cost in millions considering each combination of strategy applied by players (authors' research).

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 amount (loss -3.5 million).

Table 2. Payoff table in millions of monetary units, if GC wins the court case (the calculations include the cost of litigation dependent on the selected strategy according to Table 1; authors' research).

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).

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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 (in 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.

Table 3. Payoff table in millions of monetary units, if IN wins the court case (the calculations include the cost of litigation depending on the dependent on the selected strategy according to Table 1; authors' research).

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)

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 [24-27]) 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). Table 3 presents the game solution for game state 2, i.e. IN winning. The payoff results (Table 3) indicate that the best case for GC (Nash equilibrium) is if both players apply the conciliatory strategy. In such event GC's payoff will be 0.5 million (profit), IN – 1.5 million (loss).

From IN's perspective, for both game states, applying the conciliatory strategy is more beneficial as it minimizes IN's losses. 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.

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 [28-32]. Referring to the real conditions, the following probability distribution of two game states was 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) [33-36].

$$p_1^* * u_{GW11} + (1 - p_1^*) * u_{GW12} \geq p_1^* * u_{GW21} + (1 - p_1^*) * u_{GW22} \quad (1)$$

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.

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For GC, to effectively apply the aggressive strategy in court, there must be at least 69.23% probability (Fig. 1) that the favorable circumstances will occur and will have a decisive influence on the court's ruling.

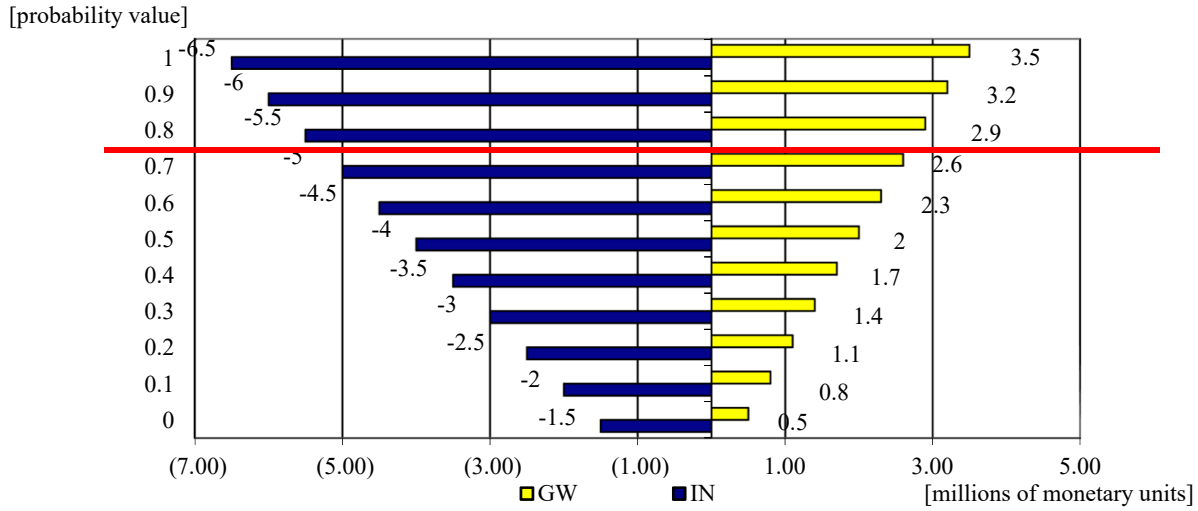

Figure 1. Simulation of the changes of expected payoffs for players (GW, IN) in millions, depending on the probability value of the judgment in favor of GC (author's research).

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).

4. Conclusions and recommendations

The aim of the game was to indicate the optimal strategy for GC in a situation of conflict with IN. Based on the analysis of the game model, expected payoffs for players were 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. 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. For GC in the first state of the game, the aggressive strategy is dominant, in the second state - the conciliatory. The conducted analysis also showed 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 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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