Journal of Industrial and Systems Engineering
Vol. 12, No. 3, pp. 1- 21
Summer (July) 2019

A game theory approach for determining optimum strategy of claim resolution in construction projects

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Abstract

Claim is a big challenge for the contractors and the owners in construction projects. Claims are considered to be one of the most disruptive events of a project. A suitable claim resolution strategy can prevent the damages to the project and the involved parties. In this research, a mathematical model using game theory is presented to find the optimum strategy for resolving cost-related claims in Design-Bid-Build (DBB) projects. The model investigates the strategies of the contractor and the owner in a consecutive four-step process including: negotiation, mediation, arbitration and litigation. It helps the involved parties to have deeper comprehension of the problem, have a better evaluation of their situation and analyze possible strategies in facing with such circumstances. Considering different scenarios, the points which both parties can agree rationally are proposed with an analytical solution. Finally, two cases of real-world problems are presented and analyzed using the proposed approach and the optimum strategy is determined for each case. Based on the results, some strategies for the owners and contractors are presented in order to be more successful in the claim resolution process.

Keywords: Game theory, optimum strategy, cost-related claim, claim resolution, construction projects.

1-Introduction

Unforeseen situations, leading to claims, are a usual feature of most of the construction projects because conditions encountered in practice are commonly different from those planned or predicted. It is a recognized fact that the number of construction claims has been increasing and it has become a big challenge for the construction industry and the involved parties. "A claim is simply an assertion of a party's right under the terms of a contract or under the law" (Hewitt, 2016). Claims are the source of many problems in the construction industry and are considered as one of the most disruptive and unpleasant events of a project (Ho and Liu, 2004). In construction, claims among contractors and the owners are very usual, particularly in DBB projects (Khanzadi et al., 2016).

Claim management refers to finding solutions for resolution of claims in a suitable period of time. Prolongation of this process leads to more costly decisions in presence of other available options. On the other hand, a good strategy for claim resolution results in reduction of the damages to the project and the involved parties, especially the owner and contractor (Khanzadi et al., 2016) and (Chen et al., 2014). The claim settlement process includes some methods such as negotiation, mediation, arbitration and litigation (Kassab et al., 2006).

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ISSN: 1735-8272,

A considerable proportion of claims in the construction industry are related to the costs of the project (Love et al., 2010). In this type of claims, the contractor (the owner) claims the other side because of the deficiency in performing the duties or the financial loss that occurs because of uncontrollable factors and/or change in project's environment (Bakhary et al., 2014).

Both the owner and contractor aim to avoid the prolongation of claim settlement process for several reasons. If a project is completed late because of the prolongation of the conflict resolution process, the owner will lose the operating profit or will suffer hidden costs because of social and political reasons. Also, the contractor might suffer from the inflation resulting from the delayed completion of the project and the increased overhead costs. The contractor will also suffer a large loss because of decreasing the reputation, losing the chance of cooperation with the contractor in future and a loss for the delay penalty (Khanzadi et al., 2016) and (Zaneldin, 2006). Therefore, both the contractor and the owner aim to find the best strategy for claim settlement in a suitable time, but with the least cost each of them pays. This is the point where the interest of the parties is placed in conflict.

In general, claim resolution is concerned with situations where the payoffs of two or more parties depend on their actions and the final outcomes are not defined by single party. Game theory can be defined as "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers" (Myerson, 2013). Among economic theories, game theory has been successfully used for many crucial issues such as negotiations and claims (Ho and Liu, 2004). Therefore, due to the nature of claims, game theory can be used to analyze the claim situation systematically and find the optimal strategy.

This paper aims to find the best strategy for the contractor and the owner to solve the cost-related claims in DBB (Design-Bid-Build) projects. The paper aims to give a deep comprehension of the structure of the claim resolution process in different scenarios and conditions. Furthermore, an analytical approach is used in order to find the optimum strategy of the involved parties for solving the claim resolution problem. Using the proposed approach, the owner and the contractor can find the best strategy to solve the cost-related claims in different conditions which would be beneficial for the contractor, the owner and also the other beneficiaries of the project.

The rest of the paper is organized as follow: A literature review is presented in section 2. The mathematical model of the transactions between the parties for claim resolution is presented in section 3. Section 4 is devoted to explain the analytical solution of the model and show the best decisions for the involved parties in different conditions. In section 5, a case study is presented. Section 6 is devoted to present the main strategies of the involved parties and finally, section 7 concludes the paper.

2- Literature review

In recent years, there have been many types of research about the claims in construction projects. These researches can be classified into three main classes: determining and analyzing the causes of the claims (Shen et al., 2017), (Mohammadi and Birgonul, 2016), (Jaffar et al., 2011) and (Zaneldin, 2006), searching for the methodologies to prevent (decrease) the claims (Song et al., 2013), (Abdoli and Khirandish, 2010) and (Acharya et al., 2006) and claim resolution approaches (Cheung et al., 2009) and (Chou, 2012). In this section, we focus on the claim resolution approaches have been used in the literature.

Many tools have been used by researchers to find the best decisions for claim resolution in projects. Kassab et al (2006) used a graph-based claim resolution decision support system that pursues the owner-contractor interplays. They used this decision support system in some researches (Kassab et al., 2010, 2011) and (Hipel et al., 2011). Risk management concept was also used as a claim resolution framework (Gebken and Gibson, 2006). Multi-attribute approaches have been used to select the best claim resolution methodology among the alternatives (Chan et al., 2006) and (Cheung and Suen, 2002). Conbere (2001) used theory building for conflict management system design. Ng et al (2007) presented dynamic conflict management in large-scale design and construction projects.

Another commonly-used approach for claim resolution in construction projects is game theory. Due to the interactive nature of claims between the parties, the game theory has been used as a powerful tool to analyze the claim situation systematically. Game theory has been used for analyzing the Opportunistic bidding behavior in construction projects (Ho and Liu, 2004), (Abdoli and Khirandish,

2010) and (Liu et al., 2017). Some researchers have applied game theory for time-related claims (The claims that occurred because of a delay from the contractor) (Castro et al., 2007), (Estevez-Fernandez, 2012), (Khanzadi et al., 2016) and (Khanzadi et al., 2017). Furthermore, game theory has been used to propose recommendations to facilitate the bargaining process in construction projects (Chen et al., 2012) and (Lv et al., 2014).

Based on the type of the game models have been used in the literature, the researches can be classified into many categories like dynamic (Ho and Liu, 2004), (Fang and Ren, 2004), (Ng et al., 2007), (Abdoli and Khirandish, 2010), (Wenxue and Jianming, 2008), (Khanzadi et al., 2016) and static (Xiaolong and Zhiyan, 2004), (Khanzadi et al., 2017), uncertain (Kassab et al., 2010), (Khanzadi et al., 2017) and certain (Ho and Liu, 2004), (Wenxue and Jianming, 2008), (Abdoli and Khirandish, 2010) and (Khanzadi et al., 2016) models.

Table 1 presents a comparative analysis of the research gaps in the literature.

Table 1. A comparative analysis of the research gaps in the literature.

Authors	Claim type		Considered methods				Hidden cost
	Time	Cost	Negotiation	Mediation	Arbitration	Litigation	
Ho and Liu (2004)		✓	✓			✓	
Fang and Ren (2004)		✓	✓				
Kassab et al (2006)			✓	✓			
Castro et al (2007)							
Ng et al (2007)			✓	✓	✓		
Wenxue and Jianming (2008)		✓	✓	✓	✓		
Kassab et al (2010)							
Abdoli and Khirandish (2010)		✓	✓			✓	
Ho and Hsu (2013)		✓	✓				
Eid et al (2015)		✓	✓				
Khanzadi et al (2016)	✓		✓				
Kanzadi et al (2017)	✓		✓				
Liu et al (2017)		✓	✓			✓	
This paper		✓	✓	✓	✓	✓	✓

As it can be concluded, although the literature on the claim resolution is abundant, there are still some research gaps that make it essential to do some new researches. One of these research gaps is that most of the studies have ignored the standard structure of claim resolution which is specified in the project management standards like FIDIC and PMBOK. In other words, most of the researches have only focused on one or two phases of the claim resolution process. However, the standard claim resolution process includes some sequential steps such as negotiation, mediation, arbitration and litigation (PMBOK, 2017) and (FIDIC, 2013). The involved parties are obliged to follow up their claims sequentially by the mentioned steps in most of the contract types. So, a comprehensive claim resolution model should contain all of the four steps in order to give a robust tool to the involved parties to have a standard claim resolution process.

Another important neglected factor in the literature is the hidden costs. Most of the researches have only considered the direct costs in the claim resolution process such as lawyer fee, consultant fee, direct cost of arbitration and litigation, management time and delays to project completion. But there are still some hidden costs in some of the claim resolution steps, especially in arbitration and litigation. Factors like contractor's reputation damage, lack of future cooperation, bad effect on other simultaneous cooperation, staff's emotional costs, reduction in working efficiency of the project, time loss of claim personnel and delayed recovery of money are some of the hidden costs of the claim resolution process (Wu et al., 2017) and (Lu et al., 2015). Ignoring these costs in the claim resolution process may reduce the efficiency of the model. Therefore, this paper considers both the direct and hidden costs in the claim resolution process.

3- Mathematical model based on game theory

In this section, an analytical model using game theory and based on the authors' own experiences is presented to study the cost claims in DBB projects. The model is called "the Cost Claims Decision Model (CCDM)". This analytical model starts by using a game tree to express the claim management process and the expected payoffs for the involved parties. The owner and the contractor are the parties involved in the claim resolution process.

3-1- Claim resolution steps

In this paper, four steps are considered for claim resolution in DBB projects based on the FIDIC (2013) conditions of contract:

Negotiation: Negotiation between the involved parties is the first step in the claim resolution process in FIDIC conditions of contract. Negotiation is the most flexible form of claim resolution as it involves the direct conversation between the involved parties and without the interference of the third party (Marzouk and Moamen, 2009). Negotiation is the least costly and informal approach of claim resolution, allowing a peaceful and low-cost resolution method for the involved parties (Lu et al., 2015).

Mediation: Mediation is a nonbinding claim resolution process, where a neutral expert is invited to help the parties to reach a suitable settlement (Cheung and Suen, 2002). In FIDIC conditions of contract, if the claim cannot be resolved by negotiation, then the mediation procedure is implemented. For mediation, the parties select a third party who helps the parties to communicate, comprehend and analyze each other's viewpoint and agree to a settlement (Alberstein, 2006). The mediator does not decide for the involved parties and his comments are not binding for the parties but help them to achieve a resolution.

Arbitration: If the parties cannot resolve their claims through the negotiation or mediation, arbitration is the next step in the claim resolution process. The arbitrator conducts a hearing, like in court, and takes a decision that binds the parties (Cheung and Suen, 2002). In the arbitration process, the involved parties can present documents and introduce witnesses which help them to win the arbitration (Thomas, 1991). The arbitrator has full power to review or revise any decision made earlier (FIDIC, 2013).

Litigation: Litigation is the final step of a settlement and is used only when a claim cannot be resolved by amicable settlement or arbitration. Since a contract is a legally binding agreement, any claim can be referred to the court of the country (Hollands, 2014). Litigation is usually the most expensive and time-consuming approach between the other three steps of claim resolution. Litigation is very complex and with a high direct and hidden costs for both the contractor and the owner (Cappelletti, 1993).

3-2- Model notation

Table 2 shows the notations used in the model.

Table 2. Notations used in the model.

Parameters	
C	Contractor's incurred cost in addition to the bid amount.
P	Contractor's first claim amount.
$P_1 = kP \quad ;\left(0<k<1\right)$	Owner's offer amount in negotiation.
$P_2 = r'P \quad ;\left(k \le r' \le 1\right)$	Amount agreed between the parties in mediation.
$P_3 = rP \quad ;\left(k < r < 1\right)$	Contractor's second offer in negotiation.
m	Contractor's incurred hidden cost as a result of contract termination.
t	Owner's incurred hidden cost and tender renewal cost as a result of contract termination.
L	Owner's financial loss for the delay occurred in project operation as a result of contract termination.
c_1	Contractor's direct and hidden cost for arbitration.
c_2	Contractor's direct and hidden cost for litigation.
e_1	Owner's direct and hidden cost for arbitration.
e_2	Owner's direct and hidden cost for litigation.
d_1	Contractor's incurred cost for compensating the delay occurred in result of the arbitration process.
d_2	Contractor's incurred cost for compensating the delay occurred in result of the litigation process.
q_1	Probability of agreement between the parties in mediation.
q_2	Contractor's success probability in arbitration.
q_3	Contractor's success probability in litigation.

3-3- Description of the game

The model is based on the FIDIC conditions of Design-Bid-Build contracts in Iran. The model was found useful for cost-related claims based on the positive comments received from the experts in the construction industry regardless of the project's delivery system. In other words, a cost-related claim resolution model is presented here which can be extended by other researchers based on requirements of projects with governing general conditions.

Before describing the assumptions and the model, some special terms used in the model are needed to be defined:

- Offer/Accept: in the case of the contractor's claim from the owner, the owner has two main alternative decisions: "accept" or "offer". If the owner finds the contractor rightful and the claim amount was logical, the owner "accepts" the contractors claim amount and compromise with the contractor. On the other hand, if the owner finds the claim amount inappropriate, he/she can negotiate with the contractor and "offer" less amount for claim resolution.
- Insist: one of the main alternative decisions of the contractor in mediation phase is "insist" on first claim amount. After the contractor's claim, the owner may negotiate with the contractor and "offer" a less amount for compromise. If the contractor finds that this offer cannot compensate his losses, he can "insist" on his first offer.

The assumptions considered in the model are listed below:

- Both the contractor and owner aim to maximize their benefits in the claim resolution process.
- The mediator can revise (ignore) all the offers of the parties in the negotiation phase.

- As the claim amount, P, increases, the probability of winning the arbitration and litigation decreases. In other words, the probability of winning the arbitration and litigation have a reverse correlation with P.
- Mediation is one of the amicable settlement methods of claim resolution. Since the time and cost of this method is very little, the cost incurred for the parties in this method is ignored.
- Since the contractor commonly starts the cost-related claims and it is a time-consuming process which usually leads to delay in the project's schedule, the contractor should propose some strategies to fulfill his/her obligations. The related costs are considered with d_1 and d_2 for arbitration and litigation phases, respectively.
- According to the red book of FIDIC, contract termination occurs when both parties intend to end the project before its completion.
- Although arbitration is a time-consuming and costly method, it is a popular approach for claim resolution in some countries like Iran (Abdoli and Khirandish, 2010). The reason is that the contractors expect that after failure in mediation, winning the arbitration leads to revenue which exceeds the total cost of arbitration and the owner's offer (Abdoli and Khirandish, 2010) and (Wenxue and Jianming, 2008). Therefore, (1) and (2) are assumed:

$$(1-q_1)(q_2)P > (1-q_1)(c_1+d_1)+kP \Rightarrow (1-q_1)\left(q_2(P)-(c_1+d_1)\right) > kP \quad (1)$$

$$(1-q_1)(q_2)P_3 > (1-q_1)(c_1+d_1)+kP \Rightarrow (1-q_1)\left(q_2(rP)-(c_1+d_1)\right) > kP \quad (2)$$

Figure 1 illustrates the game for the cost-related claims. C and O are symbols of the contractor and owner, respectively. ○ is the probability node of failure/success in each step and the two values in the bracket are respectively the contractor and the owner's payoff in the relevant game step.
First, the contractor's action is described. Suppose that the contractor's incurred cost in addition to the bid amount is C. In this case, the owner will obtain the benefit C if there is no claim. Thus, if the contractor does not claim, the payoffs for the contractor and the owner will be (-C,C), respectively.

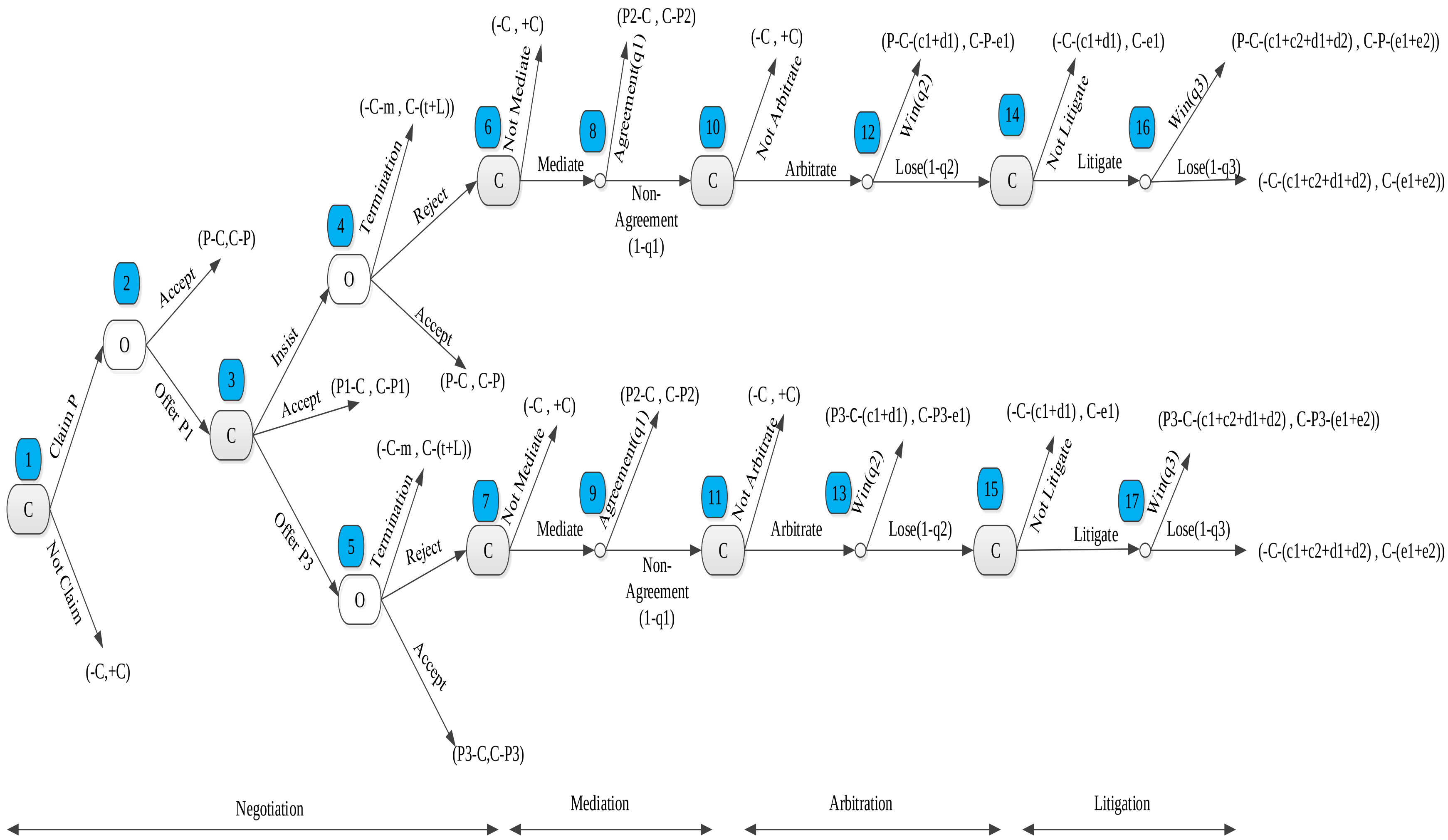

Fig. 1. Game tree for the cost-related claims resolution

Then, the owner should take the action in the case of the contractor's claim with amount P. Here, the owner has two alternative decisions: the owner will either negotiate with the contractor and offer $P_1 = kP$, where k is a ratio between 0 and 1, or accept the contractor's offer and finish the claim resolution process.

Third, the contractor should take action in the case of the owner' offer, P_1. According to figure 1, the contractor can insist on P, accept P_1 or offer $P_3 = rP$, where r is between k and 1. As shown in Fig. 1, the game tree is divided into two main branches at node 3. Here, the upper branch is described and the lower one (including nodes 5, 7, 9, 11, 13, 15 and 17) has almost the same mechanism.

If the contractor insists on his first offer, P, the owner has three alternative decisions: terminate the contract, reject the contractor's offer or accept the offer, P. In the case of termination or acceptance of the offer, the claim resolution process will be finished. But if the owner rejects the contractor's offer, the owner should decide whether to enter the mediation phase or not. In the case of selecting the mediation, the agreement will be achieved with a probability of q_1. Otherwise, the contractor can refer to the arbitrator. The total payoff if the contractor wins the arbitration is $P - C - (c_1 + d_1)$. If the result of the arbitration phase is not desirable for the contractor, he/she should decide whether to refer to the litigation or not. The payoff for the contractor if he/she wins the litigation is $P - C - (c_1 + d_1 + c_2 + d_2)$, where c_2 is the contractor's overall direct and hidden cost for litigation. Otherwise, the payoff for the contractor and the owner will be $\left(P - C - (c_1 + c_2 + d_1 + d_2),\ C - P - (e_1 + e_2)\right)$, respectively.

4- Analytical solution

In this section, the analytical equilibrium solutions for the game model of claim resolution problem are presented. In order to do so, the backward induction approach is used. In this method, the analyses start from the last node to reach the first node of each branch. The author's experiences, the experts of the construction industry's comments, researcher's studies and also the FIDIC conditions of contract are used in order to present an analytical solution for the model.

Nodes No. 14 and 16: Firstly, the last sub-game in the upper branch (nodes No. 14 and 16) is considered. Consider the contractor choose litigation at node 14. The game tree shows that he/she will win with a probability of q_3. The expected payoff for the contractor can be calculated as below:

$$q_3\left(P - C - (c_1 + c_2 + d_1 + d_2)\right) + \left(1 - q_3\right)\left(-C - (c_1 + c_2 + d_1 + d_2)\right) = -C - (c_1 + d_1) + q_3(P) - (c_2 + d_2) \tag{3}$$

Similarly, the owner's expected payoff is:

$$q_3\left(C - P - (e_1 + e_2)\right) + \left(1 - q_3\right)\left(C - (e_1 + e_2)\right) = C - (e_1 + e_2) - q_3 P \tag{4}$$

On the other hand, the contractor and the owner's payoff will be $(-C - (c_1 + d_1), C - e_1)$, if the contractor chooses "Not litigate" at node 14. In order to choose the best decision at node 14, the contractor's payoff in the cases of litigating/not litigating is compared. The contractor will litigate if $-C - (c_1 + d_1) + q_3(P) - (c_2 + d_2) > -C - (c_1 + d_1)$ or equivalently $q_3(P) > (c_2 + d_2)$.

It should be mentioned that the litigation not only entails direct costs, but also requires hidden costs like project's quality loss, involved parties' reputation damage, trust damage, lack of future cooperation and effect on other cooperation, emotional costs, reduction in working efficiency of the project, time loss of claim personnel and delayed recovery of money (Lu et al., 2015). These costs are considered in our model with parameters c_2 and e_2 for the contractor and the owner, respectively. These direct and hidden costs strongly reduce the popularity of litigation in claim resolution process (Cheung and Suen, 2002), (Hollands, 2014) and (Goldberg et al., 2014). Furthermore, considering the FIDIC conditions of contract, the delay cost for the contractor is very considerable and the contractor is obliged to compensate for the delay that caused in result of litigation (FIDIC, 2013). Since the litigation process is too time-consuming and expensive for the contractor, its popularity in claim resolution is very low (Chan and Suen, 2002). That is why the parties try to avoid litigation as much as possible and use Alternative Dispute Resolution (ADRs) which are very faster and cheaper than litigation (Gebken and Gibson, 2006). Today, referring to judge for litigation, is an unusual and rare event in the construction industry. For instance, in 2005, more than 99% of construction projects in North America used ADRs instead of using litigation (Lu et al., 2015).

Considering the time, direct and hidden costs of litigation, and the contractor has no tendency to refer the claim to the litigation. In other words, $(q_3(P)-(c_2+d_2))\leq 0$. Therefore, the contractor decides not to choose litigation and the payoff for him/her and the owner at node 14 will be $-C-(c_1+d_1)$ and $C-e_1$, respectively.

Nodes No. 10 and 12: In the case of choosing "Arbitrate" at node 12, the expected payoff for the contractor can be calculated as below:

$$q_2\left(P-C-(c_1+d_1)\right)+\left(1-q_2\right)\left(-C-(c_1+d_1)\right)=q_2P-C-(c_1+d_1) \quad (5)$$

In order to find the optimal decision at node 10, the expected payoffs for the contractor in case of selecting arbitration vs. not arbitration are compared. The contractor will refer to arbitration if the payoff from the arbitration is greater than to the payoff from not arbitrate. According to Fig. 1, the expected payoff for the contractor is –C if he/she doesn't choose the arbitration. So, if $q_2(P)-\left(c_1+d_1\right)>0$, the contractor will select arbitration. According to (1), the contractor will choose arbitration and the expected payoff for him/her and the owner will be $q_2(P)-\left(c_1+d_1\right)-C$ and $C-q_2(P)-e_1$, respectively.

Nodes No. 6 and 8: If the contractor succeeds in mediation, his/her payoff will be:

$$q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)-C \quad (6)$$

For deciding refer/not refer to mediation at node 6, (6) should be compared with $kP-C$. According to (1), the contractor's expected payoff in case of choosing mediation is more than his/her payoff in the case of not choosing mediation. So, the contractor will select the mediation and the expected payoff for him/her and the owner will be $q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)-C$ and $C-q_1\left(r'P\right)-\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)$, respectively.

Thus, the equilibration path for the reviewed sub-games is:

Contractor choose mediation $\Longrightarrow$ *If mediation is not successful, the contractor will refer to arbitration. In the case of failure in arbitration, he/she will not refer to litigation.*

Nodes No. 7-17: As mentioned before, the lower branch of the game tree (nodes No. 7- 17) has the same mechanism as the upper branch. With the same argument that used for nodes No. 14 and 16, the contractor will not choose litigation at node 15 and the expected payoff for him/her and the owner will be $-C-(c_1+d_1)$ and $C-e_1$, respectively.

In order to decide to refer/not refer to the arbitration at node 11, the same argument as presented for node 10 is used. The expected payoff for the contractor in the cases of choosing and not choosing arbitration are $q_2\left(rP\right)-\left(c_1+d_1\right)-C$ and $-C$, respectively. Considering (2), $q_2\left(rP\right)-\left(c_1+d_1\right)-C>0$ can be concluded. Thus, the contractor will select the litigation and the expected payoff for him/her and the owner will be $q_2(rP)-(c_1+d_1)-C$ and $C-q_2(rP)-e_1$, respectively.

Now, the contractor should select whether to choose the "mediation" method or not. The contractor will select the mediation if $q_1(r'P)+(1-q_1)(q_2(rP)-(c_1+d_1))-C > kP-C$. Based on (2), the expected payoff for the contractor in the case of selecting "mediation" is greater than the case of not selecting "mediation". Therefore, the contractor will select "mediation" and the expected payoff for the contractor and the owner are $q_1(r'P)+(1-q_1)(q_2(rP)-(c_1+d_1))-C$ and $C-q_1(r'P)-(1-q_1)(q_2(rP)+e_1)$, respectively.

Thus, the equilibration path for the 7-17 nodes is:

Contractor choose mediation $\Rightarrow$ *If mediation is not successful, the contractor will refer to arbitration. In the case of failure in arbitration, he/she will not refer to litigation.*

Nodes No. 1-5: This sub-game is shown in figure 2. In order to find the optimal solution for the remained section of the game tree, some scenarios are designed and the analytical solution is presented for each scenario.

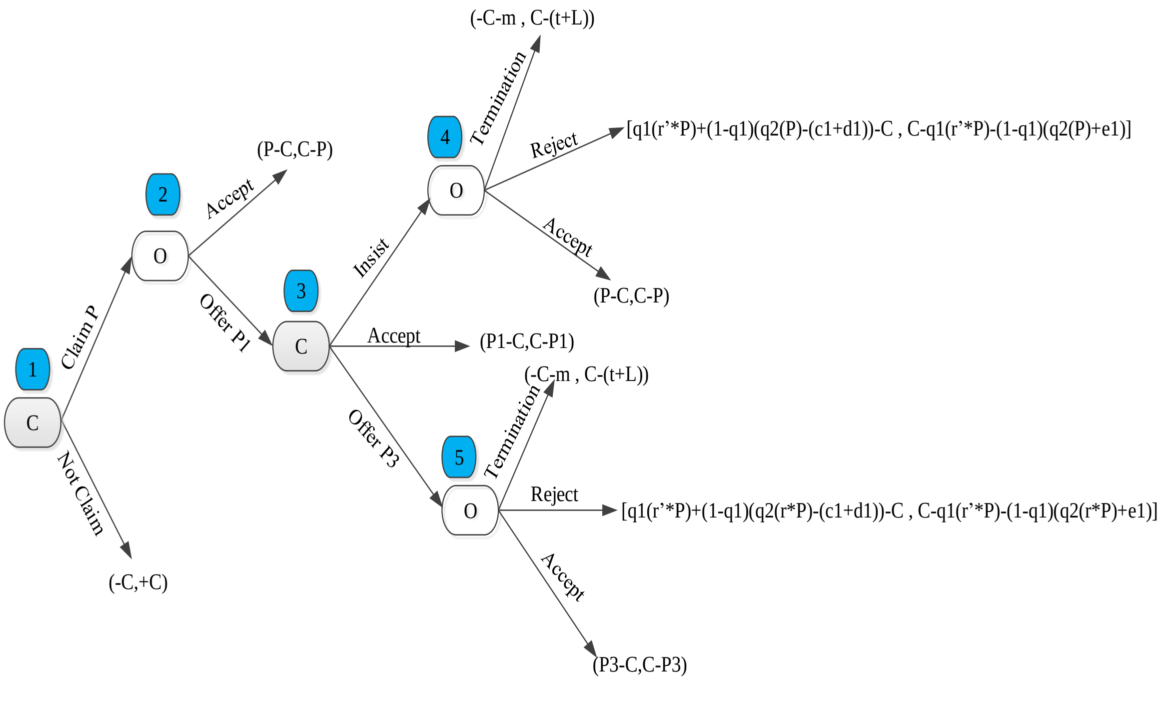

Fig. 2. Game model for nodes No. 1 – 5

Scenario 1: $q_1(r'P)+(1-q_1)(q_2(P)+e_1)<rP$

In order to find the best decision for the contractor at nodes No. 4 and 5, the expected payoff for alternative decision (termination, accept and reject) should be compared. One of the alternative decisions is "termination" of the contract. When the contract is terminated, the owner has to repeat the bidding process to select a new contractor in order to complete the project. In the owner's point of view, the contract termination suffers his/her reputation and reduces his/her prestige among the contractors. The cost incurred to the owner in this regard is called *t*. Furthermore, the owner's financial loss for the delay in project operation as a result of contract termination is called *L*. In the contractor's point of view, the contract termination damages his/her reputation in the owners' eyes; the cost incurred to the contractor in this regard is called *m* (Khanzadi et al., 2016). Considering the experts' point of view, these direct and hidden costs are very high in construction projects which lead to the reluctance of both parties to select this decision.

According to the above-mentioned facts, contract "termination" is eliminated from the owner's alternative decisions. Therefore, the owner should select whether to "accept" or "reject" the contractor's offer at nodes No. 4 and 5. Since $r<1$, $rP<P$ can be concluded. Considering (1), $q_1(r'P)+(1-q_1)(q_2(rP)+e_1)<rP$ is obvious. So, the owner will select "reject" the contractor's offer at nodes No. 4 and 5.

Now, the contractor has three alternative decisions including "insist on P", "accept P_1" and "offer P_3". Considering (1) And (2), it can be concluded that:

$$q_1(r'P)+(1-q_1)(q_2(P)-(c_1+d_1))>kP \tag{7}$$

$$q_1(r'P)+(1-q_1)(q_2(rP)-(c_1+d_1))>kP \tag{8}$$

Considering (7) and (8), "insist on P" and "offer P_3" are preferred to "accept P_1". Considering $k<r<1$, it can be concluded that $rP<P$. Therefore, (9) can be inferred:

$$q_1(r'P)+(1-q_1)(q_2(P)-(c_1+d_1))>q_1(r'P)+(1-q_1)(q_2(rP)-(c_1+d_1)) \tag{9}$$

This means that "insist on P" is preferred to "offer P_3" for the contractor. Considering (1), the best decision for the contractor at node 2 is to "offer P_1".

Finally, the contractor should decide whether to claim at node 1 or not. Since the expected payoff for the contractor in the case of claim, $q_1(r'P)+(1-q_1)(q_2(P)-(c_1+d_1))-C$, is greater than the case of not claim, the contractor will select "claim P".

Scenario 2: $q_1(r'P)+(1-q_1)(q_2(P)+e_1)\geq P$

With the same argument presented for scenario 1, "termination" is eliminated from the owner's alternatives. Therefore, the owner has two alternative decisions at nodes No. 4 and 5: "accept" or "reject" the contractor's offer. Considering (2), it can be concluded that:

$$C-q_1(r'P)+(1-q_1)(q_2(P)+e_1)\leq C-P \tag{10}$$

Thus, the owner will select "accept" the contractor's offer at node 4. Depending on the value of $q_1(r'P)+(1-q_1)(q_2(rP)+e_1)$, the contractor should select whether to "accept" or "reject" the contractor's offer at node 5. The owner will select "reject" the contractor's offer at node 5 if:

$$q_1(r'P)+(1-q_1)(q_2(rP)+e_1)<rP \tag{11}$$

Considering (11), it can be concluded that:

$$q_1(r'P)+(1-q_1)(q_2(rP)-(c_1+d_1))-C<rP-C \tag{12}$$

So, if (12) and (2) are met, "insist on P" is superior to "offer P_3" for the contractor at node 3. Otherwise, the best decision for the owner at node 5 is to "offer P_3". Also, "insist on P" has superiority to "offer P_3" for the contractor at node 3. Thus, the contractor will select "insist on P" at node 3 and his/her and the owner's expected payoff are P-C and C-P, respectively. Since the expected payoff for the owner for "accept P" and "offer P_1" is the same, he/she is indifferent between these two alternatives.

Since the payoff for the contractor in the case of "claim P" is greater than the case of "not claim", the contractor will claim P at node 1.

Scenario 3: $rP\leq q_1(r'P)+(1-q_1)(q_2(P)+e_1)<P$ and $q_1(r'P)+(1-q_1)(q_2(rP)+e_1)<rP$

The same reasoning used for scenario 1 is applied to eliminate "termination" from the owner's alternatives. Since the owner's payoff in the case of "reject" the contractor's offer is greater than the case of "accept", the owner will "reject" the contractor's offer at nodes No. 4 and 5.

Considering (1) and (2), "insist on P" and "offer P_3" are superior decisions to "accept P_1" for the contractor at node 3. In this scenario, it can be concluded that:

$$q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)-C \geq q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(rP\right)-\left(c_1+d_1\right)\right)-C \quad (13)$$

Thus, the contractor will select "insist on P" at node 3.

Now the owner should select whether to "accept P" or "offer P_1" at node 2. According to $q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)<P$ in scenario 3, it can be concluded that:

$$q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)<P \quad (14)$$

Considering (14), it can be inferred that:

$$C-q_1\left(r'P\right)-\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)>C-P \quad (15)$$

Considering (15), the owner will select "offer P_1" at node 2. Since "claim P" leads to a greater payoff than "not claim" for the contractor, he/she will "claim P" at node 1 and his/her and the owner's expected payoff in scenario 3 are $q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)-C$ and $C-q_1\left(r'P\right)-\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)$, respectively.

Scenario 4: $rP \leq q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(rP\right)+e_1\right)<P$ and $rP \leq q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)<P$

Since in this scenario, $q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)<P$ is assumed, it can be concluded that:

$$C-q_1\left(r'P\right)-\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)>C-P \quad (16)$$

This means that "reject" the contractor's offer leads to a greater payoff than "accept" the owner's offer for the contractor at node 4. Furthermore, according to $C-q_1\left(r'P\right)-\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)>C-P$, (17) can be inferred:

$$C-q_1\left(r'P\right)-\left(1-q_1\right)\left(q_2\left(rP\right)+e_1\right)\leq C-rP \quad (17)$$

Considering (17), "accept" the contractor's offer leads to a better payoff for the owner than "reject" the offer at node 5.

According to $P_3>P_1$, $P_3-C>P_1-C$ can be concluded. Therefore, "offer P_3" leads to a greater payoff than "insist on P" for the contractor at node 3. So, "insist on P" is eliminated from the alternative decisions at node 3 and the contractor should select whether to "offer P_3" or "accept P_1". In order to select the best decision, new criteria are defined. If (18) is met:

$$q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)\geq rP \quad (18)$$

The best decisions for the contractor at node No. 3 and 1 are "insist on P" and "claim P", respectively. Also, the best decision for the owner at node 2 is to "offer P_1" and the expected payoff for the contractor and the owner will be $q_1\left(r'P\right)+\left(1-q_1\right)\left(q_2\left(rP\right)-\left(c_1+d_1\right)\right)-C$ and $C-q_1\left(r'P\right)-\left(1-q_1\right)\left(q_2\left(rP\right)+e_1\right)$, respectively.

If (18) is not met, the contractor will select "offer P_3" and "claim P" at nodes No. 3 and 1, respectively.

Also, the owner will select "offer P_1" at node 2 and the expected payoff for the contractor and the owner will be P_3-C and $C-P_3$, respectively.

Finally, the equilibration path for the involved parties at each node is presented in table 3.

Table 3. Equilibration path for the involved parties at each node

Code	Scenario	Condition	Equilibration path (best decision at each node)					
			Owner (2)	Contractor (3)	Owner (4,5)	Contractor (6 , 7)	Contractor(10,11)	Contractor (14 , 15)
a	1	---	offer P_1	insist on P	reject P	mediate	arbitrate	not litigate
b	2	---	offer P_1 or accept P	insist on P	accept P	---	---	---
c	3	---	offer P_1	insist on P	reject P	mediate	arbitrate	not litigate
d	4	$q_1\left(r^{'}P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)\geq rP$	offer P_1	insist on P	reject P	mediate	arbitrate	not litigate
e	4	$q_1\left(r^{'}P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)< rP$	offer P_1	offer P_3	accept P	---	---	---

*The number in brackets shows the node number at the game tree.

Table 4 shows the expected payoff for the involved parties in each of the scenarios and conditions.

Table 4. The expected payoff for the involved parties in each scenario and condition

Code	Contractor's expected payoff	Owner's expected payoff
a	$q_1\left(r^{'}P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)-C$	$C-q_1\left(r^{'}P\right)-\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)$
b	P-C	C-P
c	$q_1\left(r^{'}P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)-C$	$C-q_1\left(r^{'}P\right)-\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)$
d	$q_1\left(r^{'}P\right)+\left(1-q_1\right)\left(q_2\left(P\right)-\left(c_1+d_1\right)\right)-C$	$C-q_1\left(r^{'}P\right)-\left(1-q_1\right)\left(q_2\left(P\right)+e_1\right)$
e	P_3-C	$C-P_3$

5- Case study

In order to show the analysis of the cost-related claims and claim resolution approach, a case study about National Iranian South Oil Company (NISOC) is used. NISOC is a government-owned company under the control of the Ministry of Petroleum of Iran and operates as a subsidiary of National Iranian Oil Company. NISOC produce about 80% of crude oil and 16% of natural gas production in Iran and ranks as Iran's biggest oil company (https://www.nisoc.ir). Since an area about 400,000km^2 is under the operations of this company, many construction and service projects are executed in NISOC at each year. Most of these projects are outsourced to the construction companies in a competitive bidding process.

In this section, two of the NISOC's construction projects that have been encountered cost-related claims are analyzed using our proposed approach.

5-1- Data gathering phase

In order to gather the data about the projects, a group of experts of NISOC was selected as the expert team. A part of the data was gathered through the documents of projects and another part was gathered using the expert team. Table 5 shows the demographic information about the expert team.

Table 5. Demographic information about the expert team

Expert code	Office	Educational degree	Age (year)	Work experience (year)
1	Engineering and Building	MSc	53	25
2	Engineering and Building	MSc	48	17
3	Legal and Contracts	BSc	56	22
4	Legal and Contracts	PhD	41	7
5	Management and Planning	MSc	55	26

Table 6 shows general information about the projects.

Table 6. General information about the projects

Project code	Project type	Estimated time (day)	Number of claims	Number of cost-related claims
1	road and well location construction	340	3	1
2	oil pipeline construction	175	2	1

After gathering some general data about the projects, the next step is to extract some more detailed information. In order to do so, data gathering process was performed by using:

- Study the documents of the project
- Using the expert team's comments
- Books, articles and other research works
- Laws of construction projects and FIDIC conditions of contract

Since one of the contractors was not available and the other contractor was reluctant to collaborate in the research process, some of the contractor's parameters that were not available in the documents were estimated by the expert team.

Table 7 shows the data of the case study.

Table 7. The data of the case study

Project code	C	P	P_1	P_2	P_3	m	t	L	c_1	c_2	e_1	e_2	d_1	d_2	q_1	q_2	q_3
1	5.209.321.103	4.670.203.131	1.808.213.114	-----	4.250.133.207	2.124.136.204	1.610.203.209	476.208.114	602.119.236	1.938.119.303	546.109.019	1.021.306.007	98.228.209	788.221.019	%28	%81	%57
2	4.860.231.119	4.550.118.006	1.146.118.207	3.488.104.211	4.008.208.126	2.008.126.304	1.388.210.300	288.131.219	405.128.236	1.528.136.219	388.113.206	840.301.166	88.309.231	766.231.119	%53	%75	%48

* All the prices are in Rials (Iran's currency).

5-2- Solving case 1

The first step to solve the problem is to check the validity of equations (1) and (2). (1) and (2) are met in case 1 according to the following equations:

$$(1-q_1)(q_2)P = 2723662466 > 2312463274 = (1-q_1)(c_1+d_1)+kP$$

$$(1-q_1)(q_2)P_3 = 2478666022 > 2312463272 = (1-q_1)(c_1+d_1)+kP$$

Considering table 7, $q_3P = 2{,}662{,}015{,}785$ is less than total litigation costs, $c_2+d_2 = 272{,}634{,}022$. This means that litigation is not a suitable method for claim resolution in this case. Considering the conditions and scenarios in Table 3, the resolution process presented for scenario 1 is the best set of decisions for the involved parties. Thus, the equilibration path for the game tree of case 1 is shown in figure 3.

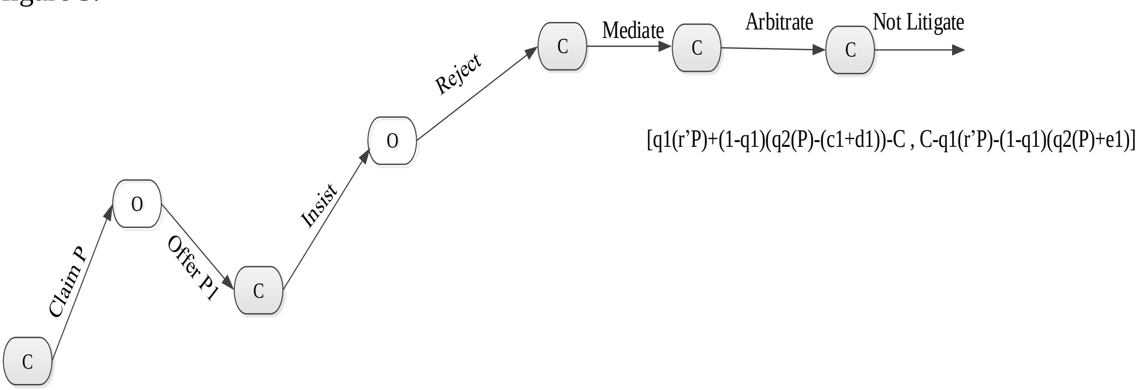

Fig. 3. Equilibration path for case 1

In practice, the contractor used the same path to solve the claim and the claim resolution process was finished by the success of the contractor at the arbitration phase. As shown in Fig. 3, the expected payoff for the contractor in this scenario (by ignoring C) is $(1-q_1)(q_2(P)-(c_1+d_1)) =$ 2,219,412,306. In reality, the contractor earned 2,033,778,563 from the owner at the arbitration phase.

5-3- Solving case 2

As mentioned in 5.2, the first step to find the optimum decisions is to check equations (1) and (2). The following calculations show that (1) and (2) are met in case 2.

$$(1-q_1)(q_2)P = 1603916597 > 1378033816 = (1-q_1)(c_1+d_1)+kP$$

$$(1-q_1)(q_2)P_3 = 1412893364 > 1378033816 = (1-q_1)(c_1+d_1)+kP$$

Since $q_3P = 2{,}184{,}056{,}643$ is less than total litigation costs, $c_2+d_2 = 2{,}294{,}367{,}338$; litigation is not a suitable method for solving the claim in this case. Considering Table 3, the equilibration path for the involved parties is shown in figure 3. Thus, the best decisions for the contractor are to refer to "mediation" at node 6 and "arbitration" at node 10 (in the case of disagreement at mediation). The contractor used the same approach and finally, the claim resolution process was ended by an agreement in the mediation phase. The amount agreed by the parties was 3,488,104,211 Rials. If the contractor doesn't accept the agreed amount and refer to arbitration, it is expected that he earn $(1-q_1)(q_2(P)-(c_1+d_1)) = 1{,}454{,}487{,}652$. Since the expected payoff in the case of arbitration is lower than the agreed amount, it is logical for the contractor to accept the agreement and end the claim.

Considering the results of the case study, the proposed approach of the paper was able to find the best decisions of the involved parties in the claim resolution process. Furthermore, an appropriate estimation of the expected payoff for each decision was presented which was near to what happened in practice. Thus, the proposed approach helps the involved parties to have the best decisions by showing the equilibration path and the expected payoff in result of each decision.

6-Strategies for the involved parties

Considering the purpose of this paper to help the involved parties in the claim resolution process, some strategies are presented for the contractors and the owners. These strategies can help the parties to be more successful in the claim management process.

6-1- Strategies for the owners

The strategies for the owner in order to be more successful in the claim management process are:

1. Increase his/her probability of winning the arbitration and litigation: reducing the contractor's winning probability in arbitration and litigation process leads to his/her frustration from tracking the claim. Therefore, one of the main strategies of the owner is to increase his/her winning probability in arbitration and litigation ($1-q_2$ and $1-q_3$, respectively) or reduce the contractor's winning probability. This strategy can be implemented by:

- Preparing an accurate and precise contract
- Performing the duties that mentioned in the contract
- Be well-prepared for the claims at any time by recruiting an experienced lawyer, prepare the documents, etc.
- Monitoring and documenting the performance of the contractor at all the phases of the project

2. Increase the contractor's cost in the claim resolution process: one of the main factors effective on claim management process is the cost that the parties incurred in this process. Increase in the contractor's cost can frustrate him/her to continue the claim management process. The main approaches that the owner can use to increase the contractor's arbitration and litigation costs are:

- Embed a considerable penalty for the delay in the contract
- Threat the contractor for non-cooperation in future works
- Notice the other owners about the claim that is started by the contractor
- Threat the contractor to terminate other ongoing projects
- Prepare well for the claim and increase the contractor's costs for a good lawyer and collect extra documents to persuade the arbitrator and judge

3. Prevent (reduce) the probability of claim occurrence: since prevention is more economical than claim resolution, one of the best strategies for the owner is to prevent cost-related claims. Using some simple instructions, the owner can decrease cost-related claims and financial loss arising from. Some of the instructions are:

- Accuracy in contractor selection
- Prevent the opportunist contractors from participating in the bidding by determining a suitable base price for the bid
- Establish a cooperative and friendly relationship with the contractor

4. Reduce his/her cost in the claim resolution process: the owner should try to manage the cost-related claims with the least possible cost. Therefore, the owner should search for some approaches to reduce his/her costs in the claim management process. This strategy can be performed by the instructions mentioned in the previous strategies, automatically.

Figure 4 shows the main strategies of the owner for the success in the claim resolution process.

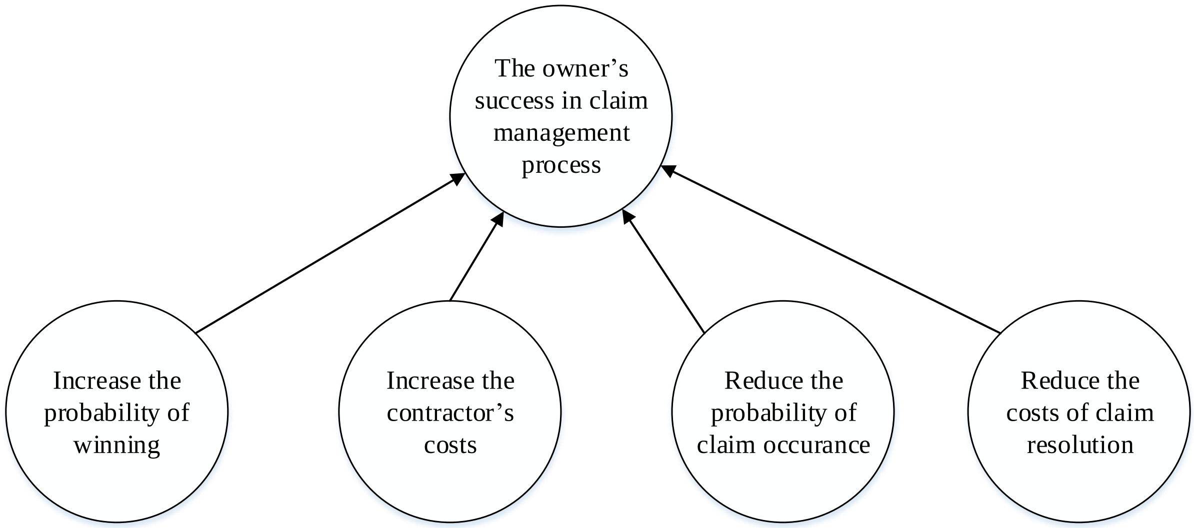

Fig. 4. The owner's strategies for success in the claim resolution process

6-2- Strategies for the contractors

The main strategies for the contractors to have better claim management process can be classified as below:

1. Increase his/her probability of winning the arbitration and litigation: the contractor should try to increase his/her probability of winning in arbitration and litigation phases (q_2 and q_3, respectively). In other words, the contractor has to reduce the owner's winning probability and frustrate him/her from the continuation of the claim. The contractor can implement this strategy by:

- Performing the duties that mentioned in the contract
- Be well-prepared for the claims at any time by recruiting an experienced lawyer, prepare the documents, etc.
- Use an experienced consultant (or lawyer) in all the phases of the project
- Documentation of the owner's deficiency in performing the duties

2. Reduce the probability of cost-related claim occurrence: considering high hidden and direct costs of claims for the contractor, the best strategy for the contractor is to prevent or reduce the probability of claim occurrence. The main methods that the contractor can use to reduce cost-related claims are:

- Accuracy in estimating the costs of projects
- Trying to reduce the costs of projects and increase efficiency
- Establish a cooperative and friendly relationship with the contractors
- Search about the owner's experiences in performing the duties before participate in the bidding

Figure 5 shows the main strategies of the owner for the success in the claim resolution process.

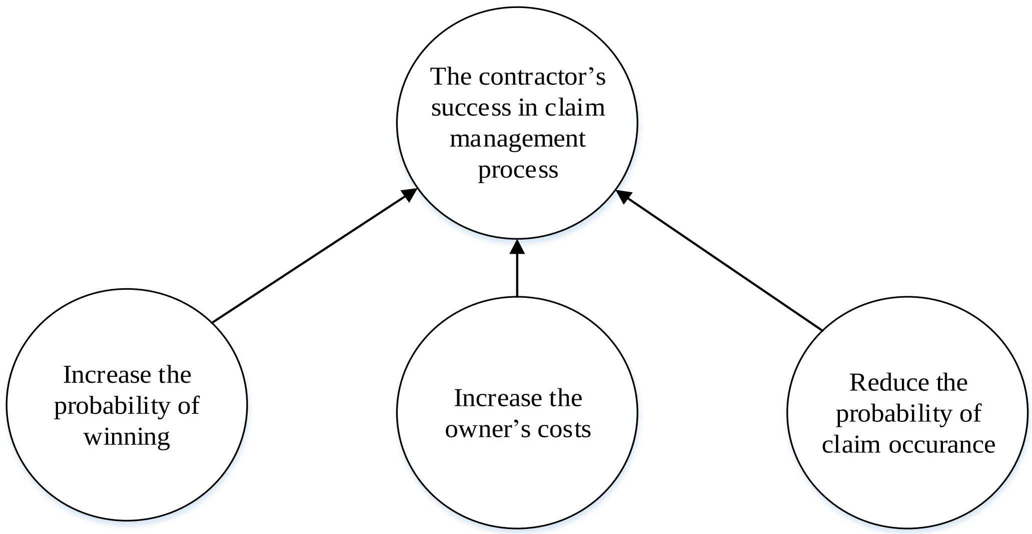

Fig. 5. The contractor's strategies for success in the claim resolution process

7- Conclusions

In this paper, a new game theory approach for determining the optimum strategy of claim resolution in DBB construction projects was devised. In order to do so, a four-step game theory approach including negotiation, mediation, arbitration and litigation was designed for claim resolution based on the FIDIC condition of contracts and the author's experiences. In order to bring the model closer to real-world conditions, both the direct and hidden costs for the parties in the claim resolution process were considered. In order to solve the proposed game model, an analytical backward solution was used based on the authors' experiences and also using experts' comments. By defining different scenarios and conditions, the best decisions at each step which constitute the equilibration path was determined. Then, the proposed approach was implemented on a case study for two of the NISOC's construction projects. The results show that the proposed approach is able to find the best decisions and estimate the expected payoff of each decision for the involved parties in the claim resolution process. Finally, some strategies and approaches that the involved parties can perform in order to be more successful in the claim management process were proposed.

Although the authors did their best to propose a comprehensive model for claim resolution, there exist some limitations in this research. Cost-related claims are dependent on the financing method of the project and the type of project management which is determined in the contract. Therefore, the mathematical model of the paper can be used only for DBB projects. However, the overall structure of the model can be adapted for some other contract types which are similar to DBB conditions of contract. Another limitation of this research is that there are many other hidden and indirect costs in the real-world and it is not possible to consider all of them in the model in order to keep the simplicity of the model.

There are various directions to improve this paper. It is possible to adjust the proposed model to use some approaches like fuzzy sets in order to account for the parameter's uncertainty. Moreover, developing a model that determines the best strategies for claim management process in other conditions of contract or under the laws of a specified country can be useful. With further research, this model can be extended for analyzing time-related claims between the owner and the contractor.

Acknowledgment

We would like to express our sincere thanks for all helps rendered to us by the National Iranian South Oil Company (NISOC) during this study.

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