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RISK MANAGEMENT AND ALLOCATION IN CONSTRUCTION PROJECTS APPLYING GAME THEORY

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Abstract

The most principal source of the emergence of claims and conflicts in the contracts of design and construction is the lack of reconnaissance and management of risks in projects. As a result, it is expected that, with the management of the recognized risks via the contractual capacities, one can prevent the emergence and instatement of such claims and conflicts in this industry to a considerable extent. In the process of risk allocation, assigning full liability of certain risks to the contractor is not correct, since it results in making certain defensive policies on part of the contractor including the quality drop and approaching towards claims and suits which, ultimately, ends in the rise of costs and time of the project. As a result, with regard to this type of risks, it is required that the liabilities caused by the risk is shared among various factors involved in the contract and thus, in other words, the quantitative allocation of risk is carried out. In the process of negotiation for determining the percentage of the risk allocated to each of the contractual parties, despite the existence of the conflict of interests to be found among these factors or agents, there is a high tendency towards collaboration and arriving at a sort of agreement. In the present research, for the quantitative allocation of risk, game theory is applied which is a branch of science for studying mathematical models of conflict and collaboration between and among rational decision-makers. The suggested model presents a highly useful tool which can sufficiently address the criteria of preference such as utility and fairness and thus specify the percentage of a fair risk allocation.

Key Words: Risk Management, Risk Management Allocation, Construction Projects, Game Theory

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设计和施工合同中出现索赔和冲突的最主要原因是缺乏对项目风险的侦察和管理。因此，预计通过合同能力管理已确认的风险，可以在相当程度上防止此类索赔和冲突在该行业中的出现和恢复。在风险分配过程中，将某些风险的全部责任分配给承包商是不正确的，因为这导致承包商对部分承包商制定了某些防御政策，包括质量下降和接近索赔和诉讼，最终以项目成本和时间的增加。因此，对于此类风险，要求由该风险引起的责任由合同中涉及的各种因素共同分担，即进行风险的量化分配。在确定分配给每个合同方的风险百分比的谈判过程中，尽管这些因素或代理人之间存在利益冲突，但合作的趋势很高，并达成某种共识。协议。在目前的研究中，对于风险的定量分配，博弈论被应用，博弈论是研究理性决策者之间冲突与协作数学模型的科学分支。建议的模型提供了一种非常有用的工具，它可以充分解决效用和公平等偏好标准，从而指定公平风险分配的百分比。

关键词：风险管理，风险管理配置，建设项目，博弈论

Introduction

Today, risk management is the necessary condition for meeting project objectives. The systematic approach towards the question of risk has given rise to the emergence of the process of project risk management which has various phases. One of such phases of this process, is risk assessment (Busch,Hangx, Marshallc & Wentinck, 2020).

The most significant use of risk assessment is the assistance it provides with accurate decision-making for choosing the solutions required to address the risk (Chebotareva, Strielkowski & Streimikiene).

Nowadays, using methods of risk assessment in various industries is on the track of expansion in a way that, presently, over 70 types of quantitative and qualitative methods of risk assessment both are available worldwide; such methods usually are applied for reconnaissance, con4trol, and reduction of the implications of threats (Sui, Ding & Wang).

Construction projects are faced with a series of risks that exert influence over the projects' function in either positive or negative ways (Chen, Zhang & Wu).

The existence of risks and indeterminacies that exist in various stages of the performance of the project play a key role in the increase of time, cost incurring, and reduction of the quality of the projects. The application of the risk management can help one in a way that, through a multi-phased process including reconnaissance, analysis, response, and risk control, the negative impacts caused by risks are reduced as much as possible and its positive impacts, on the other hand, increased (Moreno-Cabezali & Fernandez-Crehuet).

A proper risk allocation has got a vital role in the impactfulness and efficiency of the risk management cycle in a way that without proper risk allocation, this cycle is rendered inefficient and, instead of improving the function of the project, result in its function's worsening. The improper allocation of risk in it, without paying attention to the intrinsic properties of each risk, the liabilities of various agents or factors of the project in response to the risks should be determined and specified, is one of the major problems existing in the construction industry which needs to be attended to (Barghi & sikari, 2020).

In each project, various agents such as the client, counselor, and contractor are at work each of which in pursuit of a preferable management of risks existing in the area of their own liabilities (Agarwal & LalKansal, 2020). Before the commencement of the risk management process, it is required to specify that each of the agents involved in the project are liable of the risks of the project and to what extent. Defining and dividing the liability of any possible profit and/or loss caused by each of the recognized risks are part of risk allocation (Golcuk, 2020).

Game theory consists in the study of the mathematical models involved and in collaboration in decision-making method, intelligent selection, and logical decision-making in any given game. Game theory is a branch of applied mathematics used in social sciences, and, especially, in the area of economy, biology, engineering, political sciences, international relations, computer sciences, marketing, philosophy, and poker (Saraeian & Shirazi, 2020). Game theory is in pursuit of estimating behaviors in strategic conditions and in a game in which an individual's successful choice-making is pertinent upon the choices made by others (Ales, 2020). Game theory makes an attempt to provide modeling for the mathematical behavior reigning over a strategic situation (conflict of interests). This situation comes to existence whenever an individual's success is dependent upon strategies selected by others. The ultimate goal of this branch of science is finding am optimal strategy for the players involved in any given game (Deng et al, 2020).

In this project, game theory is applied for determining the percentage of the risk management allocation. The cooperation of the parties involved in the contract in the process of negotiation for the quantitative risk allocation is modeled in a manner similar to that of the presence of players in a certain game. For evaluating this suggested model, it is implemented and plotted upon one of the construction projects of Oil Company and the percentage of risk allocation between the client and contractor is determined accordingly. Game theory is formed by pursuing the percentage of risk allocation whose sum of the costs, between the client and contractor, is at the minimum. After that, in the game process, two agents, the contractor and client, make an attempt to share the profit gained through the reduction of costs. The objective of this research is applying game theory which takes into consideration the interests and stake of all parties existing in the project and creates a model for the existing conditions of negotiation process between the contractor and client and helps them to come to a real agreement acceptable by both parties which is considered so thanks to its fairness, impartiality, and lack of transgression in the temporal length of having the project fully executed and performed. With regard to the issues mentioned above, the objective of this research is the allocation of risk management in the construction projects of Oil Company with the application of game theory.

Research Methodology

In overall, each project is designed and set forth following a certain problem or question being raised. The researcher collects information and statistics needed via investigating the previous research and observing the topic background, books, essays, the internet, and proper software in order to be then in pursuit of organizing and eventually analyzing the information collected so that he or she can give response to questions, goals, and hypotheses of the research at hand. As a result, the process of gathering information and collecting data and, also, analyzing them is of great significance since theories are embodied in form of statistics and scientific facts and figures and its result is manifested in a quantitative format and the theoretical model of the research is assessable and thus calculated accordingly.

The research methodology used, tests run, and methods of data analysis were put to analysis. This part of the research, with regard to its objectives and questions, research, is divided into three main sub-divisions. In this first part of this research, the recognition of the risks in the construction projects of Oil Company are addressed. For meeting this goal, the theoretical-statistical method to be used in this research is stated with regard to the information collected through the contingent or random samples of the community under claim and then put to analysis. The result of the analyses either approves the accuracy or disapproves the research hypotheses. The second stage is allocated to giving a theoretical account of the method that can be used practically for prioritizing the impactful and comparative factors; and, in this line, a number of accounts are presented in the area of approximative methods for calculating the weights with regard to the pairwise comparison matrix and Professor Sa'ati's method which is convenient for this research. The third section addresses game theory in question which is on the basis of the discussion of competition in risk management. Game theory deals with the study of the strategic situations of the players involved in a game. The purpose of this theory is to assess the various ways of making a move in a game for accomplishing lesser risks. In such type of games, the endeavor of all players is in the direction of choosing the best strategy. The theoretical model of the game in this research the three scenarios of Stackelberg client, Stackelberg contractor, and, finally, Nash equilibrium.

Model Estimate

Risk management allocation in construction projects of Oil Company which includes the client and contractor is studied. It is assumed that both producers give their products to the same known client to have it distributed and there is no other client available in the region to create a competitive situation and thus each of the client and contractor are focused on providing costs and profit and the contractor, too, is required to control costs and profit.

1- Game Strategy

One of the fundamental points in estimating models is paying attention to the bargaining power of the members. Understanding which of these parties has a higher bargaining power in the leader-follower model is the determining factor in model estimation.

As stated above, theories in market give testimony to the existence of a higher bargaining power in an overall and general state. In the interaction between the contractor and client as Stackelberg's game/transaction, one of the partners, that is the leading or pioneering one, initiates the job and can persuade the other participant, that is, the follower, and proceed with the game. The leading or pioneering party makes the first move and the follower reacts with the proper move and with information. The purpose of the pioneering or leading party is making a design of its own move in a way that it be able to maximize its income after taking into consideration all the logical moves that the follower can make.

The difference in the higher power of each of the parties in the task of bargaining can give rise to either of these three situations:

A. Stackelberg's Contractor Situation:

The contractor has got more bargaining power over the client. As a result, the contractor is Stackelberg's leader.

$$p_i \in argmax_{pi} \| R(P_i . P_i . P_K . \dots P_l \upharpoonright W_i . S_j . W_{j.} s_j \dots w_l . s_l) \quad (1)$$

For assessing P axis in the equation above, it would suffice that a partial derivative of $\|R$ be drawn in relation with p and the optimal expression of P is gained by solving the total sum of the equations achieved.

After that, the equation of Pm is maximized for each of the contractors.

$$W_i \in argmax_{wi} \| M_i(w_i . w_i . w_k . \dots w_{l,} . s_i . s_j . \dots s_l) \quad (2)$$

$$s_i \in argmax_{si} \| m_i(w_i . s_i . w_j . s_j . \dots w_{l,} s_i, s_j, s_k, \dots s_l \quad (3)$$

Then, a derivation is made and, from solving the equations achieved, the optimal quantities of S and W in relation to $\|M_i$ for achieving the optimal quantities above, firstly, is calculated from them. The procedure of fulfilling the calculations is exactly identical to that of the two-party games.

B. Stackelberg's Client Situation:

The client has got a higher bargaining power over the client. As a result, the client is Stackelberg's leader.

$$W_i \in argmax_{wi} \| m_i(w_i . s_i . w_j . s_j . \dots w_{l.} s_l \upharpoonright p_i . p_j . \dots p_l) \quad (4)$$

$$s_i \in argmax_{si} \| m_i(w_i . s_i . w_j . s_j . \dots w_{l,} s_l \upharpoonright p_i, p_j, \dots p_l) \quad (5)$$

Then, the $\|R$ expression is rewritten in what follows as a function of P axis.

$$\|R = \sum (P_i - w_i(p_i, p_j, \dots . p_i) Q_i(p_i, p_j, \dots p_l) \quad (6)$$

By solving the linear derivative of $\|R$ in relation to P axis, one can calculate the optimal quantities of the costs for an client.

C. Nash Equilibrium

Each of the member parties has got an equal bargaining power. In Stackelberg's client game, in the beginning, profit and costs and the level of services are simultaneously determined. Then, the contractor shows its response (determining the costs) with the observation and analysis of the client's decisions. In Stackelberg's client game, the above-mentioned procedure takes place in an entirely reverse manner, meaning that, in brief, the client is the pioneering or leading party and contractor a follower of the behaviors of the client and, on the basis of the client's decisions, the costs and level of services are determined by the latter. In overall, in each of these games, initially, the function of the following party needs to be estimated in accordance with the leader's decisions. While each of the member parties simultaneously moves along Nash Equilibrium in the game.

In this research, despite the generality of Stackelberg's client game, each of the above-mentioned situations are put to analysis with the aim of for an unabridged study.

2- Stackelberg's Game

In Stackelberg's game, firstly, the function of the client's response is estimated and then the pioneering or leading party's decisions, or that of the contractor's, are studied with the aim of determining the costs and other parameters.

This point has been stated in many of the relevant research.

The client of this game is required to select two costs p_1 of P_2 and for maximizing its own equilibrium profit.

$$P_i \in \arg max_{pi}\, II_R(P_i.p_j \uparrow w_1\,, w_2, s_1, s_2) \qquad (7)$$

Where, in the above relation $II_R(P_i.p_j \uparrow w_1\,, w_2, s_1, s_2)$ – consists in the profit of the client when the costs of $p_1\ and\ P_2$ are determined by the previously made decisions of the contractor which are w_2, s_1, s_2 .

3. **Nash Equilibrium**

Nash model is studied as a criterion for both Stackelberg's client and Stackelberg's contractor. In this model, each party has got an equal bargaining power and, as a result, simultaneously, make their own decisions. This scenario exists in a project with contractors and relatively small or average others. In these markets, the assumption of being uninformed about the competitors' costs is a viable assumption and even though one can observe the costs in the project, since one client can have more influence on the project than the contractor, then making decisions over the costs is condition to the overall costs. On the other hand, the client, too, needs to condition the terms of its own decision-making over costs and profit to the costs and profits of the project as a whole. The theoretical framework of game theory is re-applied for gaining the function of the response of each game-participation; fortunately, thus far, in the sections quoted above the function of the response for the contractor and client in Stackelberg's contractor and Stackelberg's client are attained.

From Stackelberg's contractor, the function of response of the client for W_2 and W_1 costs and for s_2 and s_1 the level of services is attained through the following:

$$p_i = \frac{w_i}{2} + \frac{(b_p+\theta_p)\alpha_i+\theta_p\alpha_j}{2b_p(b_p+2\theta_p)} - \frac{\theta_s(s_j-s_i)}{2(b_p+2\theta_p)} + \frac{(b_p+\theta_p)b_s s_i+\theta_p b_s s_j}{2b_p(b_p+2\theta_p)} \qquad (8)$$

$$W_i = \frac{\pi_i B_j}{B_1B_2-D^2}\left[a_i - E_j a_j - \left(\theta_p E_j + A\right)p_i + \left(AE_j + \theta_p\right)p_j + (F_I - E_j G_i)c_i\right] \qquad (9)$$

$$s_i = \frac{B_i(b_s+\theta_s)}{B_1B_2-D^2}\left[a_i - E_j a_j - \left(\theta_p E_j + A\right)p_i + \left(AE_j + \theta_p\right)p_j\right] \qquad (10)$$

The quantities of B,D,E,A,F,G are defined in a similar line with the existing definitions of Stackelberg's client for i=1,2 and j=3-I. The simultaneous solving of the equations in question sets forth the Nash Solution. The cost, too, will be calculated in what follows.

In Nash solution, the costs of p_2 and p_1 chosen by the client are the following:

$$p_1 = \frac{(\gamma_2 k_1+\delta_1 k_2)a_1+(\gamma_2 v_1+\delta_2 v_2)a_2+\gamma_2\omega_1 c_1+\delta_1\omega_2 c_2}{\gamma_1\gamma_2-\delta_1\delta_2} \qquad (11)$$

$$p_2 = \frac{(\gamma_1 k_2+\delta_2 k_1)a_1+(\gamma_1 v_2+\delta_2 v_1)a_2+\gamma_1\omega_2 c_1+\delta_2\omega_2 c_2}{\gamma_1\gamma_2-\delta_1\delta_2} \qquad (12)$$

The above relation is in kind a linear relation between the project's size and costs.

$$\gamma_1 = 2b_p\left(b_p+2\theta_p\right)w+\mu_1 H_2(\theta_P L_2+G)b_p\left(b_p+2\theta_p\right)+\vartheta_1 H_2(b_s+\theta_s)\left(\theta_p L_2+G\right)-\vartheta_2 H_1(GL_1+\theta_p) \qquad (13)$$

$$\gamma_2 = 2b_p\left(b_p+2\theta_p\right)w+\mu_2 H_1(\theta_P L_1+G)b_p\left(b_p+2\theta_p\right)+\vartheta_1 H_1(b_s+\theta_s)\left(\theta_p L_{21}+G\right)-\vartheta_2 H_2(GL_2+\theta_p) \qquad (14)$$

$$k_1 = \mu_1 H_2 b_P\left(b_p+2\theta_p\right)+\left(b_p+\theta_p\right)w+\vartheta_1 H_2(b_s+\theta_s)-\vartheta_2 H_1 L_1(GL_2+\theta_P) \qquad (15)$$

$$k_2 = \mu_2 H_1 L_1 b_P\left(b_p+2\theta_p\right)+\theta_P w-\vartheta_2 H_1 L_1(b_s+\theta_s)-\vartheta_2 H_2 \qquad (16)$$

$$V_1 = \mu_1 H_2 L_2 b_P\left(b_p+2\theta_p\right)+\theta_P w-\vartheta_1 H_2 L_2(b_s+\theta_s)-\vartheta_2 H_1 \qquad (17)$$

$$V_1 = \mu_2 H_1 b_P\left(b_p+2\theta_p\right)+\left(b_p+\theta_p\right)w+\vartheta_1 H_1(b_s+\theta_s)-\vartheta_2 H_2 L_2 \qquad (18)$$

$$\omega_1 = \mu_1 b_P\left(b_p+2\theta_p\right)H_2(U_1+L_2 V_1) \qquad (19)$$

$$\omega_2 = \mu_2 b_P\left(b_p+2\theta_p\right)H_1(U_2+L_1 V_2) \qquad (20)$$

$$\gamma_1 = \mu_1 H_2\left(GL_1+\theta_p\right)b_p\left(b_p+2\theta_p\right)+\vartheta_1 H_2(b_s+\theta_s)(GL_2+\theta_P)-\vartheta_2 H_1(\theta_P L_1+G) \qquad (21)$$

$$\gamma_2 = \mu_2 H_1\left(GL_1+\theta_p\right)b_p\left(b_p+2\theta_p\right)+\vartheta_1 H_1(b_s+\theta_s)(GL_1+\theta_P)-\vartheta_2 H_2(\theta_P L_2+G) \qquad (22)$$

$$\varphi_1 = \theta_1 b_P+b_s\left(b_p+\theta_p\right) \qquad (23)$$

$$\varphi_2 = (\theta_p b_S-b_p\theta_p)(b_s+\theta_s) \qquad (24)$$

When the client has got the highest bargaining power, the consumers are benefitted by the lowest extent of services.

Game Theory Based on the Discussion of Risk Management Allocation

1. The formation of a game between client and contractor and the determination of the percentage of risk allocation

The goal function taken into consideration in the present research is on the basis of the minimum costs. As a result, this risk allocation can satisfy the demands of the contractor and client. As demonstrated in table (1), the best percentage of risk allocation for arriving at a fair risk allocation and, in consequence, preferable to the client and contractor is a point at which the percentage of the risk allocated to the client is 100% and for the contractor is zero. This is because, in this risk allocation percentage, the sum of the costs of the client and contractor and, in consequence, the costs of the performance of the project are at the minimum with the consideration of the risk of inflation. The contractor and client will ignore the previous risk allocation (40% to the client and 60% to the contractor) if they are certain about the reduction of their costs in the new risk allocation percentage (100% to the client and 0% to the contractor).

Table 1: the Comparison of the Contractor and Client's Costs in Two Approaches to Risk Allocation

The risk allocated to the client	Client's costs	The risk allocated to the contractor	Contractor's costs
40	120985000	0	99874000
100	129471000	60	115374000

In addition, table (1) demonstrates that the new risk allocation is beneficial to the contractor. On the other hand, this percentage of risk allocation incurs more costs to the client. The contractor prefers this risk allocation but the client. The contractor prefers this risk allocation but the client would agree to it on condition that its costs be rendered less for it in comparison with the previous situation.

1. The Results on the Basis of the Profit of the Leader and Follower

In the following table, the synopsis of the calculation and client's priority is entered in form of a pairwise comparison on the basis of the contractor's profit.

Table 2: The Matrix of the Comparisons of the Profit of the Leader and Follower in Nash Asymmetrical Model

Project 4	Project 3	Project 2	Project 1	
1/563219	1/524153	2/114529	1	Pre-assumption 1
0/965856	1/1524784	1	3/854756	Pre-assumption 2
1/524782	1	1/125355	3/485787	Pre-assumption 3
1	0/524878	1/069857	2/253543	Pre-assumption 4

Table 3: The Matrix of the Comparisons between Leader and Follower's Profit in Various Scenarios

Project 4	Project 3	Project 2	Project 1	
1/563217	1/856323	2/123589	1	Pre-assumption 1
1/1589648	1/123578	1	3/526356	Pre-assumption 2
1/524756	1	1/524868	2/524174	Pre-assumption 3
1	0/963536	1/852452	1/526338	Pre-assumption 4

Form -2

Table 4: Rating and Weighing of the Profit of the Leader and Follower in Various Scenarios

Project 4	Project 3	Project 2	Project 1	The Type of Game
0/152223	0/953209	0/748527	0/151263	NS
0/842276	0/821137	0/8112265	0/835248	BM
0/836239	0/7854263	0/652236	0/8252585	DK
4	2	3	1	Priority in all Three Comparisons

Table 5: Rating and Weighing of the Profit of the Leader and Follower in the Asymmetrical Nash Model

Project 4	Project 3	Project 2	Project 1	The Type of Game
0/171126	0/1985857	0/195247	0/165246	NS
1/325416	1/524116	1/512526	1/235127	BM
1/542189	1/635257	1/612549	1/452179	DK
4	3	2	1	Priority in all Three Comparisons

Accordign to table (5), demonstrates the interests allocated to each participant in the major coalition with the use of the Shapley Value concept. The re-allocation of the profit for a major coalition with the concept of a participatory game solution (Shapley Value) demonstrates the highest profit

Table 6: The Comparison of the Results of the Game

	$if b_s \ and \ \theta_s > 0$	$if b_s \ and \ \theta_s = 0$
Retail Price	N/A	$p^{NS} < p^{BM} < p^{DK}$
Demand	$Q^{NS} < Q^{BM} < Q^{DK}$	$Q^{NS} > Q^{DK} > Q^{BM}$
Wholesale Price	$W^{NS} > W^{DK} > W^{BM}$	
Manufacturer Profit	$\prod_N^{NS} > \prod_N^{BM} > \prod_N^{DK}$	$\prod_D^{NS} < \prod_D^{BM} < \prod_D^{DK}$
Retailer Profit	$\prod_D^{NS} < \prod_D^{BM} < \prod_D^{DK}$	$\prod_D^{NS} < \prod_D^{BM} < \prod_D^{DK}$

With regard to table (6), this comparison is based on three criteria of the production profit, customer satisfaction, distributor's profit, as decision-making criteria which are carried out separately. In addition to the fact that the method of pairwise comparisons, too, is ultimately used for rating the producers.

4-3-3- The Results of the Multi-Participant Game of the Leader and Follower in Asymmetrical Nash Model

1. On the basis of the client's profit: in this comparison, the two-party game is taken into consideration as the result.
2. On the basis of mutual satisfaction: in this comparison, the proportion of the satisfaction of the parties' satisfaction is taken into consideration as the result for a two-party game.
3. On the basis of the profit of the client and contractor: in this comparison, the profit which the contractor gains from each and any given client is taken into consideration as the result of a two-party game.

4-3-3-1- The Optimal Outputs on the Basis of Game

In the following table, the synopsis of the calculations and priority of the client is entered in form of a two-party game on the basis of the contractor's profit

Table 7: The Extent of Risk Allocation in various Scenarios

Resources	Profit	Costs		The Type of the Game
1/265	1/563	19/548	Initial allocation	NS
1/265	1/565	19/563	Optimal allocation	
0	0/10	0/29	The percentage of the changes	
1/06	1/817	19/389	Initial allocation	BM
1/07	1/817	19/391	Optimal allocation	
0/93	0	0/18	The percentage of the changes	
1/57	1/07	21/293	Initial allocation	DK
1/55	1/08	21/290	Optimal allocation	
-0/93	0/97	-0/63	The percentage of the changes	

With having the functions of the profit at hand, each of the demand knots on the basis of three game models of NS, BM, and DK one can come to risk allocation. The results of the comparison between the initial allocation and risk allocation demonstrates that risk allocation in the game model of NS, BM, and DK are changed on the basis of the allocation in relation to the initial allocation.

The changes of the risk allocation given in two initial and optimal forms has been small and for many of the models the extent of changes to be gained is zero.

In table (8), the comparison of the costs of the client is demonstrated in risk allocation in line with the method of game theory.

Table 8: The Comparison of the Costs of the Client in Risk Allocation in line with the Method of Game Theory

The quantitative method of risk allocation	Allocation stage	The risk allocated to the client	Client's costs
Game theory method	---	40	120985000
Game theory method	Game formation	100	129471000
Game theory method	After bargaining and profit distribution process	100	123657000

Table 9: The Comparison of the Client's Costs in Risk Allocation in line with the Method of Game Theory

The quantitative method of risk allocation	Allocation stage	The risk allocated to the client	x
Game theory method	---	60	99874000
Game theory method	Game formation	0	115374000
Game theory method	After bargaining and profit distribution process	0	105653000

The results of the tables (8 and 9) demonstrate the costs of the client and contractor in risk allocation in line with game theory method. By observing these tables, it is demonstrates that the costs of the client and contractor is reduced in the suggested game theory method and, in the bargaining process, whatever is the excess of profit is attributed to the contractor, the cost of this factor is reduced in comparison with the previous situation. Yet, this percentage of risk allocation can be only profitable to the contractor on condition that the minimum of 38/47 percent of the excess profit be allocated to him. In this project, the percentage of the allocated risk to the client is 100% and is 0% allocated to the contractor and the contractor takes the commitment to pay the sum of 96387250 to the client.

Table 10: Comparison of the Results of the Games

	$if b_s \ and \ \theta_s > 0$	$if b_s \ and \ \theta_s = 0$
Retail Price	N/A	$p^{NS} < p^{BM} < p^{DK}$
	$Q^{NS} < Q^{BM} < Q^{DK}$	$Q^{NS} > Q^{DK} > Q^{BM}$
Demand	$W^{NS} > W^{DK} > W^{BM}$	
Wholesale Price	$\prod_N^{NS} > \prod_N^{BM} > \prod_N^{DK}$	$\prod_D^{NS} < \prod_D^{BM} < \prod_D^{DK}$
Manufacturer Profit	$\prod_D^{NS} < \prod_D^{BM} < \prod_D^{DK}$	$\prod_D^{NS} < \prod_D^{BM} < \prod_D^{DK}$

Retailer Profit		

In the two-party game, too, it is clearly observed with regard to θ_P and b_S. Thus, the similarity of the equations is in a form that $if b_s\ and\ \theta_s = 0$ has got a logical justification.

Conclusion

In the process of risk allocation, assigning complete liabilities of some of the risks to the contractor cannot be right since it results in making certain defensive policies on part of the contractor including the reduction of the quality and turning attention to the claims and suits which, ultimately, increase the cost and time of the project. As a result, with regard to this series of risks, it is required that the liabilities caused by the risk between or among various agents involved in the contract be shared and, in other words, the quantitative risk allocation should be carried out. In the process of negotiation for determining the percentage of the allocated risk to each of the contractual parties, despite the existing conflict of interest between the contractual agents, there is a high tendency to carrying out collaboration and coming to an agreement. In this research, for the quantitative allocation of risk, game theory is applied, which is a branch of science for studying mathematical models of conflict and collaboration between rational decision-makers. The suggested model presents a powerful tool which can satisfy the criteria of preferability such as efficiency and fairness and can bring the percentage of a fair risk allocation to specification. For demonstrating the capacities of the model suggested, the percentage of risk allocation between the client and contractor, for one of the recognized risks in a project is determined. With having the functions of profit of each of the demand knots at hand, the risk allocation can be gained through three game models of NS, BM, and DK. The results of the comparison between the initial allocation and risk allocation can demonstrate that the risk allocation in the game models of NS, BM, and DK on the basis of the allocation in relation with the initial allocations have gone through certain changes. The changes in the given risk allocation, in two initial and optimal situations, was small and for many of the models demonstrate the amount equal to zero. The costs of the client and contractor are demonstrated in risk allocation in line with the method of game theory. With having observed these tables, it is demonstrated that the costs of the client and contractor in the suggested game theory method is reduced in the bargaining process whatever attributed to the contractor from the excess of profit, the cost of this agent in relation is reduced in comparison with the precious situation. Yet, the percentage of risk allocation can only be profitable for the client if the minimum of 38/47 percent from the excess of profit being attributed to him. In this project, the percentage of risk allocation to the client is 100% and that of the contractor is 0% and the latter takes the commitment of paying the sum of 96387250 to the contractor.

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