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APPLYING THE NONCOOPERATIVE GAME MODEL FOR COMPENSATION CONCEPT IN CONTRACTOR SELECTION PROCESS FOR LARGE-SCALE PROJECTS

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Abstract

Nowadays, the scale of construction projects has been larger and more complex, the tender preparation is often costly to the bidder thus. It is becoming one of the primary barriers for attracting bidder's involvement, as well as contractor's encouraging high effort. Bid compensation concept is proposed as a reward to foster the bidder participating in a higher endeavor. Game theory is ideal for modeling the dynamics and deriving high-effort strategies for bid compensation. The experiment results have demonstrated the owner can gain benefit by using rational compensation. The sensitivity analysis also shows the interest correlation between the owner and bidders. By choosing a proper strategy based on Nash Equilibrium solutions, both the owner and bidders can reach to win-win situation.

Keywords: bidding; game theory; compensation; Nash Equilibrium; large-scale projects.

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1. Introduction

The proper contractor selection task has been deemed one of the most difficult to project managers in construction projects, and the competitive tender in public projects has been regarded as a legal requirement also. In the bidding procedure, submitted technical bids are evaluated, after which the technically approved bids are evaluated financially or based on the submitted price. In line with surveying 359 construction project by Hwang [1], it is identified that the poor preparation in early stage such as deficient definition of project, inadequate planning, ineffectiveness of design, or constructibility neglected in the design step, would be the root causes of rework in execution phase. The lack of preparation in early stage is one of the main reasons for design change that significant impact on the time and cost [2]. therefore, the necessary attempts in pre-planning and design stage of projects life cycle are critical to the accomplishment of high project performance [3].

By KPMG reporting in 2010 [4], the cost of competitive bidding participation in large-scale projects might be easy to range from 0.5% to 2% of the total investment budget. The project size and complexity, the discourse duration, the level of contention of the recommendations, the quality

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of teams, and the capability of the public sector to develop its needs are some of the features that have an impact on the budgetary aspect of a private sector partner. For instance, the Design-Build Institute of America (DBIA) in 2014 [5] suggested that 'owners should offer a reasonable stipend to unsuccessful shortlisted proposers when the proposal preparation requires a significant level of effort' in the Design-Build Manual of Practice Document Number.

The supplementary efforts in early stage involve employing top-tier consultants, conducting deep professional studying further except preliminary design and analysis, and advancing value proposals. Based on attempts and experiences, the contractors should be able to have high technical proposals and effective business models that may bring to efficiency in cost and time for all stakeholders. An owner may have project management costs saving such as those associated with design, maintenance, consultation, and investigation. Thereby, practitioners have been seeking for tactics that prompt bidders to expend high effort in feasibility study during the tendering process. Compensation has been considered to be a means of enhancing the attractiveness of the tender for the private sector, moreover, its application for unsuccessful bidders may encourage bidders to spend more effort in the preliminary stage.

The definition of bid compensation is to a stipend or honorarium that the owner should consider offering to unsuccessful bidders to compensate for the effort costs incurred in the preparation [6–8]. While it seems pursuant to apply bid compensation, it has been limitation in applying circumstances and has largely been overlooked in the literature in reference to its effectiveness; the utilization of bid compensation has not been introduced in any theoretical framework or guidelines. In this research, model of game theory is developed to simulate the interaction between the owner and bidder and analyze their behaviors. A quantitative framework and the qualitative implications of bid compensation strategies are provided through the model utilizing. As the results, the research uses a mathematical method to aims to: (1) investigate the characteristics of bid compensation, (2) analyze the effectiveness of bid compensation in helping develop appropriate strategies from an owner's perspective for projects where the bid preparation costs are high, (3) add to the existing literature on tender management.

2. Literature Review

Thus far, many attempts have been studied on varying aspects of construction bidding issue. In the preconstruction stage of the BOT project, Ho [9] employed theory of game to have the problem dissection of information asymmetry during the procurement and its implication project financing and government policy. Ngai et al. [10] defined the required numbers of bidder to obtain the most competitive bid price to satisfy in condition of the cost-efficient manner in a bidding competition rely on varying market conditions. Furthermore, the game model has been applied to study-and has possibly alleviated-industry exposure to the influences of the 'winner's curse' in construction bidding environments, namely single-stage bidding and multi-stage bidding [11]. Rong Hua et al. [12] examined the strategies among the owner and contractor through a model of dynamic game to aim at mitigating the issue of cutting the corners to reduce cost at execution for the contractor proposed a low price malignantly. L. Chao and C Kou [13] constructed a model to determine the relationship of the probability of winning and project cost, using a neural network theory has assisted to optimize the minimum rate of overhead and markup, in addition, its illustration by bidding cases of Taiwan organizations. Leśniak & Plebankiewicz [14] and Al-Humaidi [15] designed a making-decision model of bid or not bid for construction bidders based on theory of fuzzy, bid/no bid decisions have been analysed depend on the most vital influencing factors, as well as suggested a ranking of various projects to bid on.

In spite of many researches related to construction bidding process as above-mentioned, the studies of bid compensation in competitive bidding have been rare. According to [6], the tender preparation in large-scale and complex projects are costly, hence the compensation policy should be considered by the owner which pay to a highest ranked unsuccessful bidder to encourage their investing high effort. A model of bid compensation built on the basic of game theory is developed to analyze the impact of compensated factor to bidders's' strategies in bidding competition. Nevertheless, the strategic interaction among a bidder and owner in the bid compensation model has not been pointed out. Whereby, the study objective is to simulate the reciprocal interaction of the owner and bidder to develop suitable tactics that may assist the owner examine the effectiveness of this approach and measure the influence level of bid compensation on the effort that a contractor puts into their proposal.

3. Research Methodology

3.1. Definition of Game theory

In the book 'The Theory of Games and Economic Behavior' written by co-author Neumann and Morgenstern's in 1944, game theory is generally considered the first time introduction. Definition of game theory can be 'the study of mathematical models of conflict and cooperation between intelligent rational decision-makers' [16]. The birth of the 'prisoner's dilemma' model by Flood & Dresher in 1950 and the definition of Nash equilibrium laid the foundations for modern noncooperative game theory. In the 1950s, game theory has been widespread through a wave of application, during which a flurry of solutions were introduced such as the conception of the core, fictitious play, model game of repetition or the extensive form, and the Shapley value. Currently, game theory is had extensive employments in whole fields of social science, logic, systems science, and computer science also ([17–21]). In construction management, game theory has been employed in various aspects, from the preconstruction stage to the construction period, to explain and predict outcomes, such as: claim decision model [22], risk management [23], design payment mechanism [24], subcontractor cooperation [25].

3.2. Methodology

In theory of game, the interaction forms based on the players's movement order are simultaneous and sequential, thus, two typical types of game includes 'simultaneous game - static game' with 'complete or incomplete information' and 'sequential game - dynamic game' with 'perfect or imperfect information'. For static game, players decide simultaneously their action without observing other's actions; this game is usually represented by a matrix form. By contrast, when a player decide his action according to observing front players's moving, it is a sequential game (dynamic game) which is expressed by the tree form. In competition environment among bidders, the strategic interactions are common among competing bidders and those between bidders and owners, and thus, theory of game can help analyze the problem of concern, as well as, usually represented by a matrix which shows the players, strategies, and payoffs (Table 1).

The game theoretical paradigm is combination of player's strategy set and their corresponding payoffs, in which, the 'best response' solution is known as maximizing payoffs their strategy choices by observing what happens of each player. To solve the game, the Nash equilibrium (NE) solution needs to be used to justify the best response for each party. The NE is a strategy profile where players have their best responses and may not unilaterally change their strategy. A pure strategy NE and or a mixed strategy NE may have simultaneous appearance in a game. In a pure strategy NE, the player

Table 1. Normal Form Game

Player 2		Left	Right
Player 1	Up	4, 3	−1, −1
	Down	0, 0	3, 4

determines their move in any situation, whereas, in a mixed strategy NE, the player randomly selects a pure strategy. A pure strategy can be regarded as a degenerate case of a mixed strategy, in which a particular pure strategy is selected with a probability of 1 and every other strategy is selected with a probability of 0. Thus, the model game of bid compensation between an owner and contractor is developed on the basis of game theory. Their strategies under various competition situations and project characteristics are presented, and the numerical results are illustrated as examples to demonstrate the manner in which the model can be used in various scenarios. The scope of methodology is shown as Fig. 1.

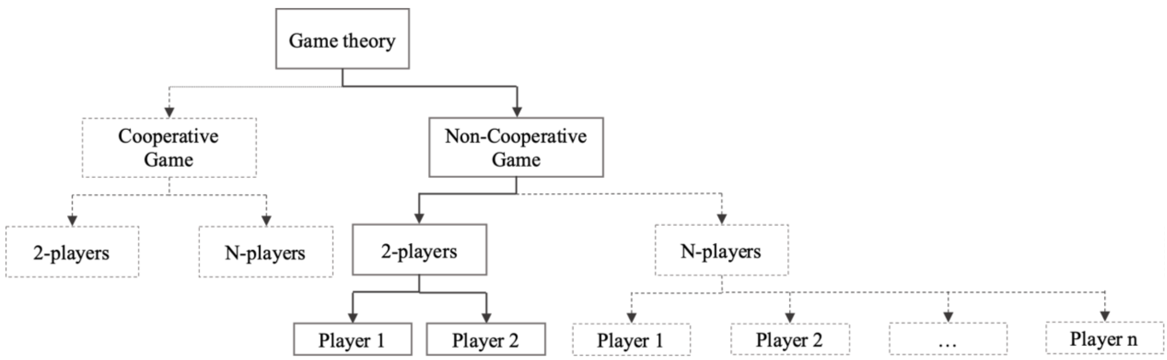

Figure 1. Scope of methodology

3.3. Assumption and Model Setup

Player and Information: owner and homogeneous bidder with complete information

Simplifications are necessary to study a model of game-theoretic and draw an interesting conclusions. It is assumed that companies entering the bidding are homogeneous the level of capability and experience. The game of competitive model is set up for the owner and contractor role. In the condition of complete information, player's payoffs can be reasonably calculated by other players, including profit margins and extra effort costs.

Payoffs

The payoffs of the model are set up based on the following components in Table 2.

3.4. Model Development

For a certain scenario, the model of the player's payoff will be shown in each possible equilibrium. The possible equilibria include Nash equilibrium of pure strategy and mixed strategy. In a mixed strategy NE, the probability of playing 'S' and that of playing 'No S' are modeled for the owner,

Table 2. The modeling components

Components	Notation	Description
Marginal profit	P	The highest profit of the contractor shall be achieved
Bid compensation	S	Bid compensation is assumed for the second rank bidder
Type of effort	The assumed types of effort are high and average levels, denoted by 'H' and 'A', respectively.	
	H	The level 'H' of effort is set as the level that contractor will provide supplementary study for proposal based on preliminary information and incur extra cost, which is indicated as E, to heighten the quality of a proposal, where the enhancement is recognized by an effective proposal evaluation system. Technically, the evaluation criteria and their respective weights specified in the requirement have been converted from the standard of quality.
	A	Conversely, the level 'A' of effort is established as the level that meet the typical requirements in tender document and does not incur any suggestions for improving quality purpose.
The additional cost for extra effort	E	For the sake of simplicity, it is assumed that E will be separated with the tender price thereby the contractor need to consider the price-quality competition to win the contract for conducting high effort.
The probability	a	The probability of winning chance when contractor plays strategy 'H'
	$1 - a$	The probability of losing chance when contractor plays strategy 'H'
	b	The probability of winning chance when contractor plays strategy 'A' ($b \leq a$)
	$1 - b$	The probability of losing chance when contractor plays strategy 'A'
Ratio of effort	α ($0 < \alpha \leq 1$)	It is assumed that the strategy 'No S' of the owner may influence to contractor's decision in playing a high effort strategy. It represents the level capacity of contractor ($0.7 < \alpha \leq 1$: strong to very strong contractor, $0.3 < \alpha \leq 7$: regular contractor, $0 < \alpha \leq 0.3$: weak contractor) also.

denoted by v and $1 - v$, respectively. And, for the bidder, the probability of playing strategy 'H' and that of playing strategy 'A' are modeled, which is represented by u and $1 - u$, respectively. For each bidder in the game, their possible payoffs are indicated in a normal form as Table 3.

- If the bidder selects 'H' and win with probability $a\%$, and the owner chooses 'S', denoted by 'S, H', the bidder will get profit as (aP) and bid compensation as ($(1-a)S$) and reduce the amount of extra cost for effort H as ($-E$), the owner will save the amount of extra cost as (aE) and reduce the amount of bid compensation as ($(1-a)S$), so the expected payoff is $aE-(1-a)S; aP-(1-a)S-E$.

- If the bidder selects 'A' and win with probability b% ($b \leq a$), and the owner chooses 'S', denoted by 'S, A', the bidder will get profit as (bP) and bid compensation as ($(1-b)S$), the owner will only reduce the amount of bid compensation as ($(1-b)S$), so the expected payoff is $-(1-b)S; bP-(1-b)S$.

- If the bidder selects 'H' and win with probability $\alpha a\%$, and the owner chooses 'No S', denoted by 'No S, H', the bidder will get profit as ($a\alpha P$) and bid compensation as ($(1-a)S$) and use amount of extra cost by αE for effort 'H' as ($-\alpha E$), the owner will save the amount of extra cost as ($a\alpha^2 E$) and reduce the amount of bid compensation as ($(1-a\alpha)S$), so the expected payoff is $a\alpha^2 E; a\alpha P-\alpha E$.

- If the bidder selects 'A' and win with probability $b\%$, and the owner chooses 'No S', denoted by 'No S, A', the bidder will only get profit as (bP), the owner will get nothing, so the expected payoff is $0; bP$.

Table 3. The expected payoffs of the owner and the bidder

Player 2 – Bidder		H	A
Player 1 – Owner	S	$aE-(1-a)S$ $aP+(1-a)S-E$	$-(1-b)S$ $bP+(1-b)S$
	No S	$a\alpha^2 E$ $a\alpha P-\alpha E$	0 bP

4. Result and Discussion

4.1. Pure Strategy Nash Equilibrium

In this game, there are four possible Nash equilibrias as (S; H), (No S; A), (S; A), and (No S; H).

First, check equilibrium $[(S;H);(aE-(1-a)S;aP+(1-a)S-E]$. For the owner (player 1) not to deviate from $[(S;H);(aE-(1-a)S;aP+(1-a)S-E]$ to $[(NoS;H);(a\alpha^2E;a\alpha P-\alpha E)]$.

$$aE-(1-a)S > a\alpha^2 E \Rightarrow E > S(1-a)/\left(a-a\alpha^2\right) \tag{1}$$

is needed.

Otherwise, for the bidder (player 2) not to diverge from $[(\mathrm{S;H});(\mathrm{aE}-(1-a)S;aP+(1-\mathrm{a})\mathrm{S}-\mathrm{E}]$ to $\left[(\mathrm{NoS;H});\left(\mathrm{a}\alpha^2E;a\alpha P-\alpha E\right)\right]$

$$aP+(1-a)S-E > bP+(1-b)S \Rightarrow E < (\mathrm{P}-\mathrm{S})(\mathrm{a}-\mathrm{b}) \tag{2}$$

Consequently, the existing equilibrium solution will be (S; H) when

$$S(1-a)/\left(a-a\alpha^2\right) < E < (\mathrm{P}-\mathrm{S})(\mathrm{a}-\mathrm{b}) \tag{3}$$

Second, examining equilibrium of $[(\mathrm{NoS};A);(0;\mathrm{bP})]$. For the owner not to change strategy from $[(\mathrm{NoS};A);(0;\mathrm{bP})]$ to $[(\mathrm{S},A);(-(1-b)S;\mathrm{bP}+(1-\mathrm{b})\mathrm{S})]$

$$0 > -(1-b)S \Rightarrow \text{ always satisfied} \tag{4}$$

For the bidder not to deviate from (NoS; A) to $\left[(\text{NoS}; \text{H}); \left(\text{a}\alpha^2\text{E}; \text{a}\alpha\text{P} - \alpha E\right)\right]$

$$bP > a\alpha P - \alpha E \Rightarrow E > P(a\alpha - b)/\alpha \tag{5}$$

Thus, condition (5) alone will warrant (No S; A) to be a Nash equilibrium. There are two clues in condition (5). In view of this, when extra cost (E) is large, the bidder will be pushed to play 'A'. The reason is that, when E is large, the profit of the contractor will be reduced, in consequence, the contractor can achieve the project whether playing 'H' or not. On another note, the implication in Eq. (5) also is that, when the bidder tends to choose playing 'A', the owner will not offer bid compensation. Therefore, (No S; A) will be the equilibrium solution when E is large.

Third, check equilibrium [(S; A); (−1(1 − b)S; bP + (1 − b)S)]. For the owner not to shift from (S; A) to [(NoS; A); (0; bP)], the model have got to check:

$$0 > -(1 - b)S \Rightarrow \text{ impossible} \tag{6}$$

For the bidder not to deviate from (S; A) to [(S; H); (aE − (1 − a)S; aP + (1 − a)S − E)], the model has to have:

$$bP + (1 - b)S > aP + (1 - a)S - E \Rightarrow E > (P - S)(\text{a} - \text{b}) \tag{7}$$

Since Eq. (6) cannot be satisfied, (S; A) can not be equilibrium.

Finally, check the (No S; H) equilibrium. As follow the similar rationale, for (No S; H) to be the solution, the modeling condition has to be

$$a\alpha^2 E > aE - (1 - a)S \Rightarrow E < S(1 - a)/\left(a - a\alpha^2\right) \text{ (for the owner)} \tag{8}$$

and condition

$$a\alpha P - \alpha E > bP \Rightarrow E < P(a\alpha - b)/\alpha \text{ (for the bidder)} \tag{9}$$

On the one hand, when E in become larger, the bid compensation will be increased parallel, as a result, the owner will be referred to using strategy No S. Therefore, (No S; H) will become the equilibrium solution when E is large.

To summarize, there are (S, H), (No S; A), (No S; H) three possible pure strategy NE which is satisfied above conditions as Eq. (3), (5), (8), (9).

4.2. Mixed Strategy Nash Equilibrium

In a mixed strategy, each pure strategy is assigned a probability. A player is allowed for random selecting a pure strategy. A numerous of available mixed strategy for a player will be existing due to the continuous nature of probability. Following the concept of equilibrium, the mathematical requirement for the equilibrium probabilities is that each player's mixed strategy equilibrium probabilities will make the other player indifferent to potential strategies (Gibbons 1992).

As aforementioned, the bidder's probability of choosing 'H' is u be and v be the owner's probability of choosing 'S'. The conditions for the equilibrium probabilities are that equilibrium probability u^* has to poise the owner's payoffs and make the owner apathetic to choosing 'S' and 'No S' and that equilibrium probability v^* has to make the bidder apathetic to choosing 'H' and 'A'. Consequently, the equilibrium probabilities must satisfy the following two conditions:

First, there is analyzed the balancing payoffs of the owner by the bidder using u^*

$$\begin{gathered}[aE - (1 - a)S]u^* - (1 - b)S\,(1 - u^*) = a\alpha^2 Eu^* + 0\,(1 - u^*) \\ \text{(balancing payoffs of owner)}\end{gathered} \tag{10}$$

To logical similarity, for the owner to use v^*, considering the balancing payoffs of the bidder

$$[aP + (1-a)S - E]v^* + (a\alpha P - \alpha E)(1 - v^*) = [bP + (1-b)S]v^* + bP(1 - v^*) \quad \text{(balancing payoffs of bidder)} \tag{11}$$

Solving Eqs. (10) and (11)

$$u^* = [(1-b)S/E] / \left[a\left(1-\alpha^2\right) + (a-b)S/E\right] \tag{12}$$

$$v^* = [(a\alpha - b)P/E - \alpha] / [(a-b)S/E + (1-\alpha) - a(1-\alpha)P/E] \tag{13}$$

are acquired.

Additionally, since the constraint for the probability of mixed strategy is that

First, $0 < u^* < 1$

$$\begin{aligned} &\Rightarrow 0 < [(1-b)S/E] / \left[\mathrm{a}\left(1-\mathrm{a}^2\right) + (a-b)S/E\right] < 1 \\ &\Rightarrow 0 < S/\mathrm{E} < a\left(1-\alpha^2\right)/(1-a) \end{aligned} \tag{14}$$

Second, $0 < v^* < 1$

$$\begin{aligned} &\Rightarrow 0 < [(a\alpha - b)P/E - \alpha] / [(a-b)S/E + (1-\alpha) - a(1-\alpha)P/E < 1 \\ &\Rightarrow \alpha/(a\alpha - b) < P/E < S(a-b)/E(1-b) + 1/(1-b) \end{aligned} \tag{15}$$

4.3. The Analysis of Bid Compensation Effectiveness in Game

As stated by Figs. 2 and 3, generally, the contractor has a tendency to use strategy 'A' due to when the decreasing of ratio α, and the probability u^* diminishes accordingly. Alternatively, if the ratio α is kept constant, the probability u^* tends to increase at the high amount of bid compensation. To observe Fig. 2, at $\alpha = 0$ - unfavorable case (weak contractors), the probability of contractor's choosing strategy H is 20% and might be up to 50% at bid compensation amount increasing from a half to double effort cost (E); however, that probability is unchanged at $\alpha = 1$ (it means strong contractors). It is concluded that bid compensation significantly impacts to weak or regular contractor's decision.

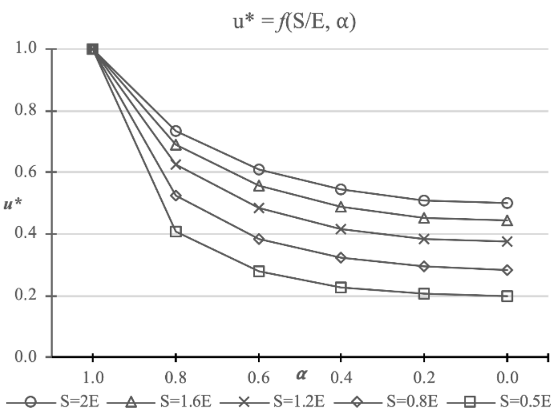

Figure 2. Probability u^*

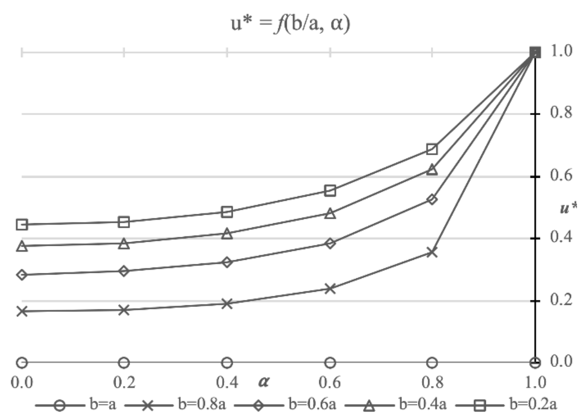

Figure 3. Probability u^*

In Fig. 3, case $b = a$ implies that contractor could win the bid whether using strategy 'H' or 'A', the bidder always chooses strategy 'A' in any case thus. If it is the remarkable difference of the advantage in playing strategy 'H' & 'A', the bid compensation effects the increasing of probability u^* when the ratio b/a declines as shown in Fig. 4.

As result shown in Figs. 5 and 6, at point $\alpha = 0$, bidding participants have weak or medium level, the owner has tendency to choose strategy 'S' to aim at encouraging extra effort of contractor in preparation, hence the probability v^* is high. As Fig. 5 performed, the owner's decision is had tiny influence regardless of the varying amount of compensation. In particular Fig. 5, when the ratio α touches to the value of 0.6, all the curve of probability v^* advance toward zero. The reason the owner tends to choose 'No S' because of attending of strong contractor in the project.

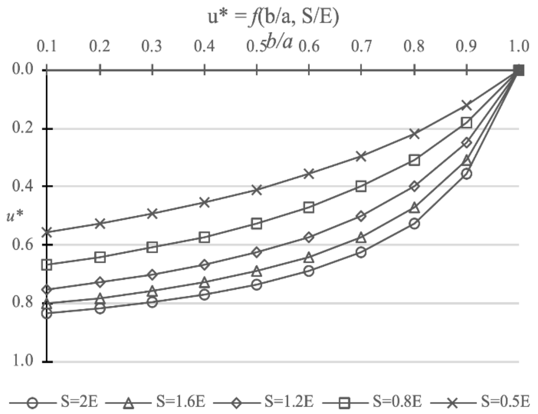

Figure 4. Probability u^*

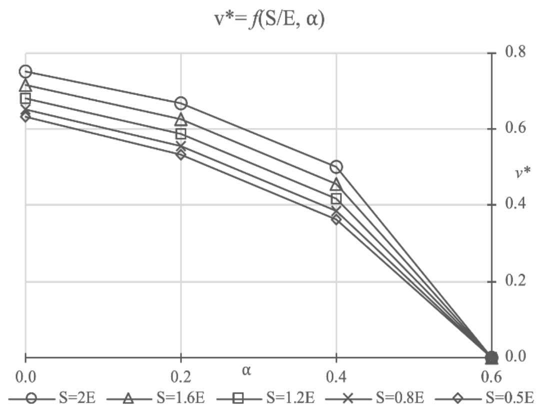

Figure 5. Probability v^*

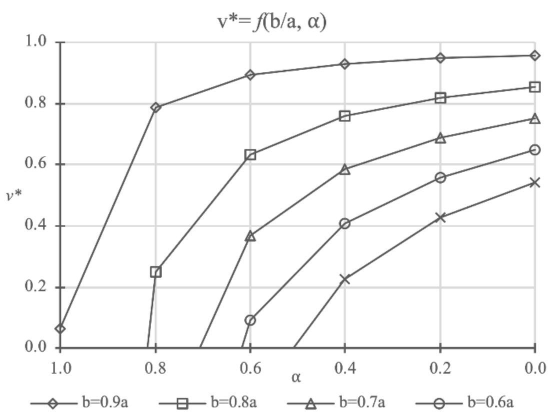

Figure 6. Probability v^*

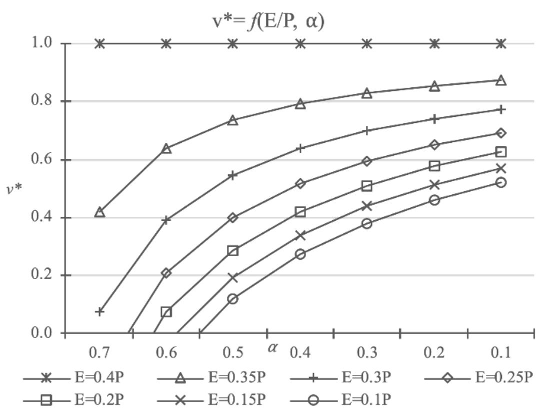

Figure 7. Probability v^*

In Fig. 6 expressed, the ratio b/a reduces that influences to the playing tactic 'S' decision of owner, since the bidder could enhance the wining ability only by making an extra effort for preparation. As Fig. 7, the probability v^* dwindles for strong and very strong bidding participants ($\alpha > 0.7$), and grows due to the rise of ratio E/P. For weak contractor ($\alpha = 0$), it has 50% of playing strategy 'S' by the owner and up to 100% when extra effort cost is nearly equal to half of the contractor's profit (E = 0.4P).

4.4. *Model verification: Bid Compensation and Procurement Strategies*

Referring to the previous studies, the research proposes the input parameters for the model and its result as follows (Tables 4 and 5).

Table 4. The chance of bidder's playing high effort

INPUT		OUTPUT					
		$\alpha = 0.5$			$\alpha = 0.7$		
P = 10%	E	S = 1%	S = 2%	S = 3%	S = 1%	S = 2%	S = 3%
a = 95%	2%	0.267	0.430	0.541	0.879	Always	Always
b = 50%	3%	0.193	0.329	0.430	0.475	Always	Always
	4%	0.152	0.267	0.357	0.325	0.879	0.774
	5.50%	0.114	0.208	0.285	0.221	0.536	0.563
	6.50%	0.098	0.181	0.251	0.182	0.426	0.476

Table 5. The chance of the owner's offering bid compensation

INPUT		OUTPUT					
		$\alpha = 0.5$			$\alpha = 0.7$		
P = 10%	E	S = 1%	S = 2%	S = 3%	S = 1%	S = 2%	S = 3%
a = 95%	2%	0.379	0.439	0.521	N/A	N/A	N/A
b = 50%	3%	0.625	0.745	0.921	0.300	0.429	0.750
	4%	0.978	Always	Always	0.958	Always	Always
	5.50%	Always	Always	Always	Always	Always	Always
	6.50%	Always	Always	Always	Always	Always	Always

Table 6. Mixed Strategy Probabilities in a Four-Bidder Game. Adapted from 'Bid compensation decision model for projects with costly bid preparation' by Ho [8]

E; P = 10%	Equilibrium				
	4H	3H + 1A	2H + 2A	1H + 3A	4A
E < P/4 e.g., E = 2%	S < 22%	N/A	N/A	N/A	S > 22%
P/4 < E < P/3 e.g., E = 3%	2% < S < 18%	0 < S < 2% S = 0, q = 0.829 S = 1%, q = 0.914	N/A	N/A	S > 18%
P/3 < E < P/2 e.g., E = 4%	6% < S < 14%	2% <S < 6% S = 2%, q = 0.697 S = 4%, q = 0.854	S < 2% S = 0, q = 0.578 S = 1%, q = 0.632	N/A	S > 14%
P/2 < E < (3/5)P e.g., E = 5.5%	N/A	6.5% < S < 8% S = 6.5%, q = 0.550 S = 7.5%, q = 0.661	3% < S < 6.5% S = 3%, q = 0.341 S = 5.5%, q = 0.457	S < 3% S = 0, q = 0.296 S = 1%, q = 0.306	S>8%
(3/5)P < E < (3/4)P e.g., E = 6.5%	N/A	N/A	N/A	S < 4% S = 0, q = 0.140 S = 2%, q = 0.102	S > 4%
(3/4)P < E	N/A	N/A	N/A	N/A	Always

Note: N/A = respective equilibrium does not exist.

According to results shown in Tables 4, 5 and 6, the meaningful judgments regarding the formation of bid compensation strategies are concluded as follows:

- Based on the complexity of project, the bid compensation strategies can be considered. The amount of additional effort is required for amelioration that might reflect the project complexity, which is represented as E in this paper. And it tends to be inefficient for project that has characteristic either really simple or highly complex.

- Based on Table 4, the compensation amount obviously impacts to the decision of contractor's using tactic 'H'. It's alike to previous research outcome as indicated in Table 6, which the possibility of bidder's playing high effort heighten as the amount of compensation rising.

- Besides, for unique projects that required high aesthetic and state-of-the-art technology application, the aspect of marginal cost-benefit should be considered thoroughly to have the best decision of whether to use bid compensation and its amount. For those cases, the compensation suggestion in bidding process has been regarded as inappropriacy, although its effectiveness is observed clearly.

5. Conclusions

The model of bid compensation contributes to the strategy analysis when the positions of owner and bidder have been studied, and assists to make the decision of proper bid compensation via different theoretical frame provided. From the owner's point of view, the paper outcome shows that the model outcome shows that the possibility of bidder's investing high effort in bidding process is depending on the capacity level of contractor, the project complexity, the difference of advantages between using strategy "H" and "A" and the proportion of bid compensation amount and additional cost of more effort. Thus, it is recommended that the owner should spend a bid compensation strategy to weak (or regular) bidders only, and determine bid compensation magnitude to achieve the desired efficiency. Whereas, from the contractor's viewpoint, it is pointed out that two major factors, namely the complexity of the project and the capability of the contractor, have the certain influence to owner's chance of paying bid compensation strategy. The study is suggested that the contractor can be confident to invest highly effort for high complexity projects.

In this study, the noncooperative game model has been applied to analyze the bid compensation problem. Its effectiveness is assessed through dissecting several factors in various circumstances of construction procurement. To aim at studying economic behavior by all of participants and extract precious implications from problematic scenarios, this model is built on the specified set-up of assumptions that defined at the threshold of the model included homogeneous bidders and information of completeness. Thus, the bid compensation model should be contemplated the utilization in the particular situations. Note that the result of study only expresses the trends by analyzing the relationships of P, S, E parameter, as well as, the worthy model is proposed for the owner and contractor. For the future work, it is suggested that the multiple purposes shall be reflected by relaxing these strict presumptions. Also, the collected data from empirical survey and integrated algorithm should be supplemented to upgrade the effectiveness of incentive mechanism in motivating higher quality of the proposal, as well as, the accuracy of player's payoff determination.

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