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Dynamic Gaming and Risk-Incorporated Bargaining Decision Support Model for Strategic Alliance Projects

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Abstract: Increasing demand for differentiated products and services promotes project businesses, and many project-based strategic alliances have become innovative business solutions to obtain synergistic competitiveness in the highly competitive market. However, while two profit-oriented companies intend to form a strategic alliance for an expected return, it is very difficult to reach an agreement in terms of sharing risks and rewards. If the risks and rewards are not properly shared in the bargaining process, the alliance would be unstable for long-term business. Thus, a bargaining decision support model is needed to estimate acceptable rewards of the cooperative parties. This is crucial to ensure a win-win situation in the bargaining. In this paper, game theory, fuzzy set theory, and utility theory are used as complementary methodologies to develop a risk-incorporated bargaining decision support model (RBDSM) for supporting business pricing decisions in project-based alliances. Factors of bargaining power and cooperation risk are considered in the proposed RBDSM. The model can properly support decision makers in examining equilibrium prices under various bargaining conditions. A case study is provided to demonstrate the model's applications and benefits.

Keywords: Pricing, Negotiation, Decision Support System, Game Theory, Utility Theory, Risk Assessment

1 Introduction

The emergence of project businesses has changed the traditional business practices and organizational forms. Project-based organizations have been increasingly observed in modern marketplaces. With the increasing scale and complexity of projects, the business environment has become more challenging, and a single company can no longer manage a complicated project alone. The desire and search for collaborators to achieve synergistic competitiveness is the prime motive for companies to collaborate [1]. Project-based alliances are especially popular in the construction industries. In recent decades, large and complex construction projects and the application of alternative procurement systems such as design-build (DB) and build-operate-transfer (BOT) has increased [2-3]. Companies are increasingly participating in construction projects by means of joint ventures (JVs) [4]. A proper JV can bring about diverse benefits to participating companies, such as technology transfer, risk sharing, cost reduction, knowledge sharing, resource complementarities, team building for better qualification, and access to international market [5-10]. Thus, JV has become one of the most efficient project-based alliances in response to the modern market.

While two profit-oriented companies intend to cooperate and form a strategic alliance for a particular project, it is relatively easy to divide the work scope based on each party's specialty, but it is always difficult to reach an agreement in terms of sharing risks and rewards. The sharing of rewards is usually done by arranging separate amounts of the expected total rewards or by sharing proportionally, depending on the collaborating relationships among the JV team. Once companies have different objectives in the strategic alliance project, conflicts and bargaining within the strategic alliance team will be inevitable [11-12]. The "zone of agreement" in the bargaining can be estimated by deducting the lowest acceptable price for each party from the total amount [13]. As each party strives for its maximum price in the "zone," bargaining is usually carried out through numerous offers and counter offers until an agreement is reached or the bargaining is abandoned.

In the construction industry, forming collaborations between JV parties are usually a short-term and unique challenge. Not only the complex work breakdown structure should be negotiated in a short period but also the time allowed for bargaining is strictly limited by the established bid submission deadline. Thus, a timely evaluation of different bargaining situations and acceptable prices to both parties is critical for the success of a JV project. In practices, few operational research models are available to help companies resolve the bargaining problem. Thus, to satisfy both parties, a bargaining decision support model is crucial for estimating the acceptable rewards of the cooperative parties. It is also important for enhancing the possibility of a win-win situation and the success of reaching an agreement in the bargaining process.

In this paper, we propose a risk-incorporated bargaining decision support model (RBDSM) to support strategic bargaining decisions. The model, based on Game Theory, can assist participants to estimate mutual acceptable prices and individual bottom line prices with the considerations of the bargaining power and risk of cooperation. Bacharach and Edward [14] have pointed out that the outcome of bargaining is highly influenced by the bargainer's level of dependence on the bargaining outcome. Accordingly, the variable, need for revenue from the project, is used to represent a company's bargaining power in a JV project. In addition, Mislin et al. [15] stated that the success of a negotiated agreement depends on implementation and implications for future exchanges between the parties. Thus, the partners' qualifications and reputation constitute certain risks for the cooperative project. The aforementioned bargaining power and risk factors are considered in the proposed model by incorporating fuzzy sets and utility-based assessment methods. The integrated model enables strategic-alliance companies to estimate their bargaining positions in different cooperative cases and dynamically select proper bargaining strategies in a systematic and rational manner for better businesses.

2 The Bargaining Model

In this paper, game theory, fuzzy set theory, and utility theory are used as complementary methodologies to develop a model (RBDSM) for supporting business-pricing decisions in real world applications. Game theory, "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers," has been successfully applied to many important areas, including negotiations, finance, and business strategies. It allows researchers to find mathematical solutions for conflict situations [16]. The game theory perspective helps decision makers take into account not only the competitor's current strategy, but the competitor's forthcoming responsive actions as well [17]. Based on the concept of Rubinstein Sequential Bargaining Theory (RSBT), the bargaining game between two parties of a JV team is modeled as a sequential bargaining process [18]. In this model, the JV parties are termed as "players."

2.1 Sequential Bargaining Process and the Equilibrium

The main idea of the RSBT is an iterative offer and counteroffer process. For a total reward, E, bargaining begins with the offer proposed by player A in round 1 (n=1), and there are three possible responses from player B: (a) accepts the offer, (b) rejects the offer and closes the bargaining, and (c) makes a counteroffer. If player B makes a counteroffer, then similarly, player A may accept, reject, or make a counteroffer to player B. Usually the bargaining is an offer-counteroffer process until the nth, when an agreement is reached, or the bargaining is abandoned. Accordingly, different rewards or losses in each round are expected. At the nth, it could be player A's or player B's turn to make the offer.

How players behave in the sequential bargaining process can be understood by the concept of "Nash equilibrium." In the Nash equilibrium, each player's strategy should respond to the other player's strategy, and no player wants to deviate from the equilibrium solution [19]. Accordingly, the equilibrium price of a sequential bargaining process is the best price for both parties under the sets of available information and bargaining situation. The equilibrium of sequential bargaining has been solved through Backward

Induction Method [20]. According to this method, whether a player accepts the counterpart's offer depends on his expectation of rewards in the next round. Only when the reward offered by the counterpart exceeds or equals what is expected would a player accept the offer and settle the agreement.

Yan [20] has proposed an equilibrium price function as Eqn. (2.1):

$$a^* = C_a + \frac{C_a F_p S_b}{C_b S_a + C_a S_b} \quad (2.1)$$

where a^* represents player A's best offer in the bargaining, C_a represents the estimated cost of player A, C_b represents the estimated cost of player B, F_p represents the total profit of the project, S_a represents company A's need for the project, and S_b represents company B's need for the project.

2.2 Estimation of Bargaining Power

Power can be defined in terms of influence over others and power differences can significantly affect bargaining outcomes [21]. Eqn. (2.1) can be promptly used to suggest player A's offer as an acceptable price for both parties. Based on the equilibrium price function, a company's need for the revenue from a project is the bargaining power. A company with a relatively high need for the project is likely to lose more of the bargaining power and consequently the profit from the JV project. In Eqn. (2.1), C_a, C_b, and F_p usually can be identified before bargaining, while S_a and S_b are key variables affecting the estimation of acceptable prices. Fuzzy sets can be properly used to qualify S_a and S_b. Previous research has proposed three factors, "received revenues"(R), "future business opportunities"(F), and "level of competition"(L) for the estimation of a company's need for revenue (S). To deal with imprecise data or linguistic variables as aforementioned, fuzzy sets would be an acceptable approach in helping decision making [22].

2.3 Risk Assessment and Transaction Cost

Yan [23] has proposed that, in a construction JV, the potential monetary loss induced by the risk of an inter-organizational transaction, should be considered as a transaction cost. There are two types of alliance risk identified: relational and performance [24]. Relational risk is the risk of opportunistic behavior of one of the partners having negative impacts on the other [25]. Performance risk is the probability that an alliance may fail even when partners commit themselves fully to the alliance [26]. In this section, the transaction cost perspective is adopted and a utility-based risk assessment model is presented.

Although the equilibrium price can be determined by Eqn. (2.1), the risk of specific JV projects should be taken into account for assuring the profit gained from the strategic alliance. This is especially true in international JV projects when foreign investors have to face an unfamiliar construction environment and high risk is involved [27-28]. Since risks are inherent in a JV project due to the uncertainty of the partner's performance, it might induce a monetary loss. The impacts of the risks on the profit gained from the strategic alliance can be modeled as Eqn. (2.2):

$$D_r = f(r_i) \times f(P_r) \quad (2.2)$$

where D_r represents the estimated ratio of profit loss with risk considerations, $f(r_i)$ represents a risk assessment function for JVs, $f(P_r)$ represents a profit loss function based on the risk assessment.

Thus, Eqn. (2.1) should be further modified for comprising the concept of risk management. For example, assume that certain risks are inherent in a JV project due to the uncertainty of the partner's performance. The expected profit might be reduced by then. If one company wants to retain the expected profit, the risk discount factor can be considered by Eqn. (2.3):

$$a_r = a^*(1 + D_r) \quad (2.3)$$

where a_r represents the estimated acceptable price with risk considerations.

In this paper, functions of risk assessment are developed based on utility theory, which has been an accepted approach used to provide an objective decision based on subjective, qualitative data [29-30]. Utility theory requires utility functions that quantify qualitative decision criteria. In this paper, utility functions are used for considering decision makers' individual preferences and attitude towards risk when selecting an appropriate scale within the risk ranges. The utility functions can also be used to convert the evaluation score of each criterion into comparable ratings.

Among 70 influential JV risk factors, a set of criteria including technical risks, management risks, market risks, financial risks, and political risks was proposed [31]. Based on the research results, 25 criteria are considered in this paper for the assessment of JV project risk. Quadratic utility functions are developed for each criterion as shown in Table 1. For a project-based risk assessment, the expected utility value (EUV) can be calculated by Eqn. (2.4). The higher the EUV is, the lower the overall risk is.

$$EUV = \sum_{i=1}^{n}(u_i \times W_i) \quad (2.4)$$

where u_i represents the estimated utility for criterion *i*, W_i represents the weights accounted for criterion *i*.

For budgeting purposes, the cost effect function of risk can convert the EUV into potential estimated profit loss (EPL) so that the decision makers feel better informed, with more comprehensible information. Based on a cross-national questionnaire survey, previous studies have found that there are three different results from surveyed project targets by comparing the JV EUVs with real profit records. Among successful JV projects, the real profit is 1-2 % less than expectations. In contrast to this, among ineffective JVs projects, the real profit is about 8% less than expectations and 20% less than the expected profit for the failed projects. As Eqn. (2.5), an EPL function of risk has been proposed by [23] based on the aforementioned survey results:

$$EPL = 2.5EUV^2 - 9.5EUV + 8 \quad (2.5)$$

Table 1. The criteria and utility function for risk assessment

Criteria	Scale	Utility function
Agreement	High = 100; Low = 0	$y(u_i)= 0.000375\ u_i^2-0.0175u_i\ -1$
Renegotiation	Easy = 100; Impossible = 0	$y(u_i)= 0.00026667\ u_i^2-0.006666667\ u_i\ -1$
Good relationship	Yes = 100; No = 0	$y(u_i)= 0.00026667\ u_i^2-0.006666667\ u_i\ -1$
Past work	Records per year	$y(u_i)= -0.15\ u_i^2+1.15\ u_i\ -1$
Current work	Yes = 100; No = 0	$y(u_i)= 0.00026667\ u_i^2-0.006666667\ u_i\ -1$
Historic profit	% / year	$y(u_i)= -0.0037037\ u_i^2+0.15185185\ u_i\ -0.148148$
Regulation & law	Good = 100; Poor = 0	$y(u_i)= 0.00026667\ u_i^2-0.006666667\ u_i\ -1$
Bank credibility	Good = 100; Poor = 0	$y(u_i)= 0.000083\ u_i^2+0.0117\ u_i\ -1$
Engineering contract	High = 100; Low = 0	$y(u_i)= 0.000375\ u_i^2-0.0175\ u_i\ -1$
Duration	Good = 100; Poor = 0	$y(u_i)= 0.000889\ u_i^2-0.0689\ u_i\ -1$
Cash flow requirement	Yes = 100; No = 0	$y(u_i)= 0.000375\ u_i^2-0.0175\ u_i\ -1$
Complexity	Yes = 100; No = 0	$y(u_i)= 0.000083\ u_i^2+0.0117\ u_i\ -1$
Project type	Yes = 100; No = 0	$y(u_i)= 0.000083\ u_i^2+0.0117\ u_i\ -1$
Subcontractors	Easy = 100; Impossible = 0	$y(u_i)= 0.00026667\ u_i^2-0.006666667\ u_i\ -1$
Technical skills	Good = 100; Poor = 0	$y(u_i)= -0.00003125\ u_i^2+0.0231\ u_i\ -1$
Machines and tools available	Good = 100; Poor = 0	$y(u_i)= -0.00003125\ u_i^2+0.0231\ u_i\ -1$
Project allocation	Good = 100; Poor = 0	$y(u_i)= -0.00003125\ u_i^2+0.0231\ u_i\ -1$
Employment	Good = 100; Poor = 0	$y(u_i)= 0.000083\ u_i^2+0.0117\ u_i\ -1$
Policy change	High = 0; Low = 100	$y(u_i)= -0.02\ u_i\ +1$
Interest and exchange rate fluctuation	High = 0; Low = 100	$y(u_i)= -0.02\ u_i\ +1$
Fairness	Yes = 100; No = 0	$y(u_i)= 0.000375\ u_i^2-0.0175\ u_i\ -1$
Public facilities	Yes = 100; No = 0	$y(u_i)= 0.000083\ u_i^2+0.0117\ u_i\ -1$
Market demand	High = 100; Low = 0	$y(u_i)= 0.000375\ u_i^2-0.0175\ u_i\ -1$
Competition	High = 0; Low = 100	$y(u_i)= -0.02\ u_i\ +1$
Material fluctuation	%	$y(u_i)= -0.033333\ u_i^2-0.2335\ u_i\ +1$

3 Applications and Case Study

In this section, a two-company JV case is benchmarked based on the information from previous studies [20, 23]. There was a project which consists of 5.5 km of tunneling work and a substation. The estimated contract amount of the winning bid is $3,229 million dollars. It is agreed that company A handles the station portion and company B handles the tunnel portion.

Based on the initial estimation, the highest price of company A is cost (C_a) + estimated total profit (F) = 1,180 million dollars + 279 million dollars = 1,459 million dollars. On the other hand, the highest price of company B is C_b + F = 1,770 million dollars + 279 million dollars = 2,049 million dollars. However, under the limited total budget, these highest prices are not feasible to be mutually accepted by both parties. Therefore, to modify the expectation on rewards and make a relatively feasible offer, both parties need to confirm their estimations on important bargaining variables, including cost and the need for the project. If the cost estimation is relatively reliable, companies should collect more information about each party's need for the project and estimate the values of S_a and S_b. Assume that S_a and S_b estimated by company A are 0.58 and 0.83, respectively, based on the perceived status of each party's "received revenues," "future business opportunities," and "level of competition." Then company A can apply the equilibrium price function to infer that it may earn 1,316.22 million dollars while company B may receive 1,912.78 million dollars. However, based on an evaluation of company B's qualification, certain risk is considered by company A. Therefore, company A would take into account the potential loss of profit.

Table 2. The weighted utility for the case study

Criteria	Weights (optional)	Evaluation			Weighted Utility		
		y_p	y_m	y_o	Most pessimistic	Most optimistic	Three points
Agreement	10.96%	60	80	90	-0.0767	0.0507	-0.0076
Renegotiation	8.74%	75	80	85	0.0000	0.0315	0.0152
Good relationship	6.96%	70	80	85	-0.0111	0.0251	0.0100
Past work	2.95%	4	5	6	0.0354	0.0148	0.0295
Current work	4.41%	40	60	80	-0.0370	0.0076	-0.0194
Historic profit	0.67%	50	8	10	-0.0122	0.0067	0.0088
Regulation & law	3.99%	30	60	80	-0.0383	0.0069	-0.0192
Bank credibility	1.32%	60	75	80	0.0000	0.0062	0.0040
Engineering contract	9.01%	80	85	90	0.0000	0.0417	0.0200
Duration	11.96%	30	40	75	-0.2711	-0.1396	-0.2761
Cash flow requirement	5.06%	70	99	99	-0.0196	0.0506	0.0365
Complexity	2.49%	70	99	99	0.0056	0.0249	0.0214
Project type	1.47%	60	99	99	0.0000	0.0147	0.0120
Subcontractors	3.48%	70	80	90	-0.0056	0.0195	0.0060
Technical skills	2.14%	60	75	85	0.0059	0.0158	0.0116
Machines and tools available	2.28%	30	40	70	-0.0076	0.0106	-0.0013
Project allocation	1.45%	30	40	60	-0.0049	0.0040	-0.0013
Employment	0.65%	40	50	80	-0.0026	0.0030	-0.0009
Policy change	6.31%	90	50	30	-0.2095	-0.0050	-0.0738
Interest and exchange rate fluctuation	1.63%	99	99	50	-0.0652	-0.0163	-0.0559
Fairness	3.77%	5	20	50	-0.0406	-0.0353	-0.0454
Public facilities	1.63%	20	50	80	-0.0119	0.0076	-0.0034
Market demand	3.05%	80	90	95	0.0000	0.0220	0.0128
Competition	0.84%	60	50	30	-0.0017	0.0034	0.0003
Material fluctuation	2.77%	4	5	6	-0.0129	-0.0443	-0.0277
Expected Utility Value (EUV)					-0.7818	0.1265	-0.3440
Estimated Profit Loss (EPL) (%)					16.9546	6.8381	11.5642

From the perspective of company A, one of the most critical success factors for this JV practice is to determine a comprehensive project budget as well as a price baseline for the station construction work packages, so as to support the quotations in the bargaining stage and cost controls in the execution stage. Based on the work packages and historical cost data, the production cost is estimated as 1,180 million dollars. To further consider the possible risk of cooperation as well as the transaction cost, the foreign company's qualification can be evaluated based on the proposed risk assessment model. Three-point estimates can be used to define a range of possible outcomes in numerical terms so that probabilistic risk assessment and subsequent analysis can be performed for a more comprehensive decision. As shown in Table 2, the most optimistic estimate (y_o), most likely estimate (y_m), and the most pessimistic estimate (y_p) for each criterion and the potential loss induced by the cooperation risk can be determined. As for the three-point estimate, the estimated loss of profit is 11.5642% less than the predicted profit, while the EPL is 6.8381% and

16.9546% for the most optimistic and most pessimistic situations, respectively.

If both parties have a similar recognition of S_a and S_b, the agreement can be easily reached. Otherwise, if each party's perceptions differ, conflicts may be incurred in the bargaining process. In this situation, both parties should check the accuracy of the information received and, as more information is exchanged between both parties, the proposed equilibrium price function would be very supportive, which is a timely and rational approach to help adjustments on pricing strategies. With the quantitative analysis, irrational alternatives can be detected and eliminated, and thus achieve the goals of rational decision making [32].

Consider a case that company A can make sure that S_a is 0.58, while S_b is not definite. The acceptable rewards in different bargaining positions can be estimated by the proposed model. Note that the estimation of high S_b represents that company A takes an optimistic bargaining position and low S_b for pessimistic bargaining positions. As shown in Fig. 1, the suggested offer based on different sets of S_b can be calculated. Similarly, company B can lock S_b (suppose it is 0.83) and infer company A's possible offers based on different sets of S_a (the rewards that are willing to be shared by company B in Fig. 1). In this case, once the reward company B is willing to share is more than the acceptable reward for company A, the agreement can be made. For company A, the acceptable reward with different risk considerations can be determined and the feasibility of the agreement can be evaluated by comparing the acceptable reward and the reward company B is willing to share. In the bargaining process, company A should take any offers higher than the acceptable reward with risk considerations. Although individual bargaining positions may change during the offer and counter-offer process, the bottom lines should be kept in mind when making offers to company B. Thus, these objective evaluations give each company a clear guideline for pricing.

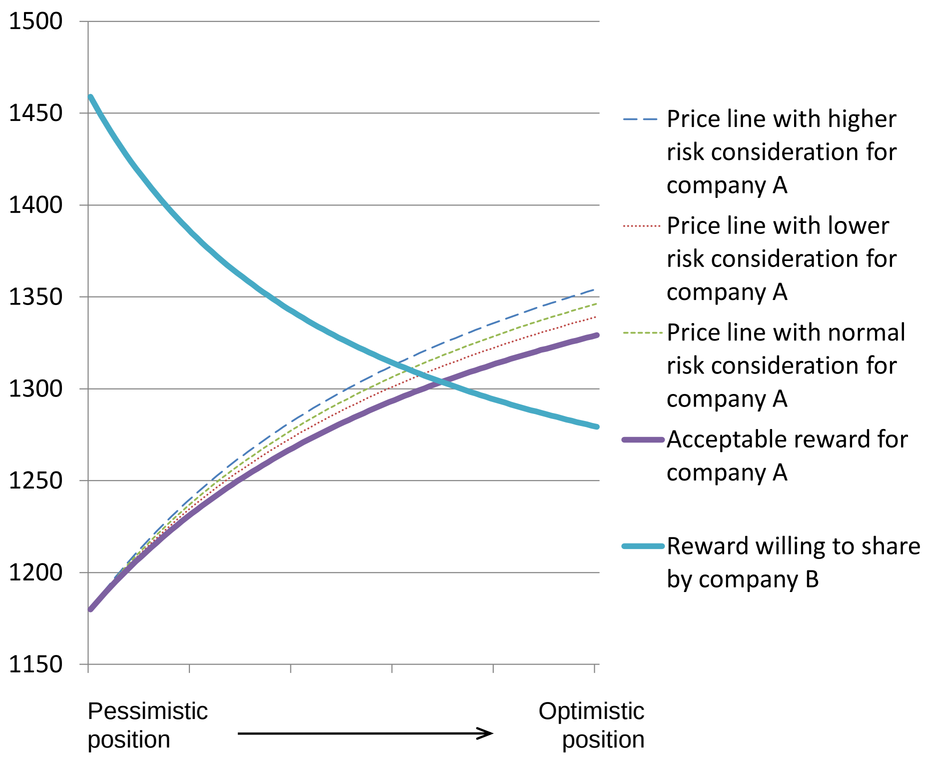

Fig. 1. Bargaining positions and suggested price lines under different risk considerations

4 Conclusions

Making pricing decisions in the bargaining process is a challenge to every participant. Emotional and psychological factors can induce inconsistent judgments and pricing decisions in the bargaining process. Thus, a bargaining decision support model is important because it can enhance the rationale of offers and counteroffers then ensure right business with other partners. In this paper, we successfully take bargaining power and the risk of cooperation into consideration in the process of making bargaining decisions so that production cost, transaction cost, and opportunity cost can be properly estimated to establish price lines in the bargaining. Although the concept of equilibrium price has been theoretically analyzed in previous studies, the assumption of perfect information for pricing is not close to the real bargaining cases. If the required information is incomplete, companies inevitably need update their information, review their estimations, and confirm their price lines in the bargaining process. The proposed model enables JV parties to determine the best price, based on each party's cost, the specified bargaining power, and the risk of the cooperation, and thus the tasks of dynamic gaming and price analysis can be systematically performed.

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