Bargaining Strategies for Construction Joint Ventures by Fuzzy Logic

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Abstract

As the modern construction market and environment encounter drastic changes, a single company alone can no longer manage a complex project and satisfy project owner's needs. Joint venture (JV) of companies, formed to integrate various expertises, becomes a necessity to obtain competitive advantages to ensure survival in the fiercely competitive market. While two profit-oriented companies intend to form a JV for a particular project, it is relatively easy to divide the work scope by each party's specialties, yet to reach an agreement on the sharing of rewards is always a challenge. This research developed a sequential bargaining model with fuzzy logic for JV parties to estimate acceptable prices of both parties. The research results can assist JV companies to select their bargaining strategy in a systematic and rational manner.

Keywords: bargaining, joint venture, fuzzy logic.

1. Introduction

In recent decades, the construction projects have become larger and more complex, and the application of various alternative procurement systems such as design-build (DB) and build-operate-transfer (BOT) have been increased. A growing number of construction projects have exceeded the scope that can be handled solely by a single company. Thus joint venture (JV) has become an important method for construction companies in response to the increasing demands in the construction industry [1].

The forming of construction JV teams is quite different from strategic alliance in other industry because the time for negotiation is strictly limited. During a short tendering period (usually not longer than four weeks for large projects) announced by public agencies, JV teams should overcome challenges including (a) partner(s) selection, (b) bid preparation, and especially, (c) negotiation on the sharing of rewards for each party's work scope. Since both parties are enterprise entities pursuing their max profits, the conflicts of interest make the smooth completion of bargaining a challenging task. Lai [2] pointed out that bargaining is induced when a conflict lies between participating parties, so repeated offer-and-counteroffer communications and compromises are required to reach an agreement.

Raiffa [3] proposed the concept of "zone of agreement", which can be figured out by deducting the lowest price of each party from the total amount. Each party repeatedly strives for the optimal price, which can be accepted by both parties, in the "zone". Usually such cyclic process repeats until an agreement is reached, or the bargaining is given up.

To find the optimal price, Rubenstein [4] proposed the equilibrium solution of sequential bargaining process with perfect information. In most real world cases, however, information for pricing always features a certain degree of ambiguity, making Rubenstein's concept becomes infeasible. Thus, this research aims to develop a sequential bargaining model with fuzzy logic rules to handle the ambiguous information and assist company to find their optimal pricing decision in a rational manner, under the assumptions that during the bargaining process, information of each party's cost spent in the bid preparation and execution of work is already known, and each party's demand for the project is not.

2. Modeling the sequential bargaining process

The bargaining between two parties of a JV team is modeled as a sequential bargaining process. In this model, the participants are termed as "players".

Basic symbols in the model

- *k:* Participants in the bargaining model, in which k=1 refers to player A while k=2 refers to player B.
- *n:* Round of bargaining.
- *E:* Total contract amount estimated through announced budget information and market price before negotiation. The total contract amount is a fixed bidding price which is assumed to win the bid. As agreement is reached, $E=x^*+y^*$, in which x^* refers

to payment obtained by player A, and y^* refers to payment obtained by player B.

- x_n: Player A's offer for its works in the n^{th} round.
- y_n: Player B's offer for its works in the n^{th} round.
- C^k: Cost estimated by the player k according to individual work scopes (including bid preparation cost). Since information associated with market prices of materials and labor is quite open, it is assumed that both parties in the bargaining can obtain clear awareness of each other's cost.
- F: Total profit of the project. $F=E-C^1-C^2$.
- Bc^k: The bid preparation cost shared by player k.
- P: Probability of failure in the bargaining. In this model, the failing probabilities of each bargaining round are the same.
- L_n^k : Expected loss when agreement is not settled. The "loss" includes the cost previously paid for bid preparation and potential profits in the project.

The sequential bargaining model

It is assumed that bargaining begins with the offer proposed by player A in round *1* ($n=1$), and there are three possible reponses from player B: (a) accepts the offer, (b)rejects the offer and closes the bargaining, and (c)rejects the offer and makes counteroffer. Usually the bargaining is an offer-counteroffer process until the n^{th} round, an agreement is reached, or the bargaining is given up. As players propose different offers in each round, both parties would have different expectation on rewards or loss (as shown in Table 1).

Table 1. The sequential bargaining process

Round	Possible Responses	Payoffs
Round *1*: Player A offers a price x_1	Player B accepts the price	$[x_1,E-x_1]$
	Player B rejects the price and closes the bargaining	$[-L_1^1,-L_1^2]$
	Player B rejects the price and makes counteroffer	to round 2
Round *2*: Player B offers a price y_2	Player A accepts the price	$[E-y_2,y_2]$
	Player A rejects the price and closes the bargaining	$[-L_2^1,-L_2^2]$
	Player A rejects the price and makes counteroffer	to round 3
After repeated offers and counteroffers		
Round n: Player A offers a price x_n	Player B accepts the price	$[x_n,E-x_n]$
	Player B rejects the price and closes the bargaining	$[-L_n^1,-L_n^2]$

The equilibrium of sequential bargaining

In order to understand how players behave in the sequential bargaining process, this research introduced the concept of "equilibrium" [5]. An equilibrium solution is one not threatened by increasingly intelligent analysis of the situation; the more the players think of their situation, the more likely they are to converge on the equilibrium solution. In equilibrium, each player's strategy should respond to the other player's strategy, and no player wants to deviate from the equilibrium solution which is the one would eventually converge under the aforementioned situation. Thus, the equilibrium price of sequential bargaining process is an optimal price for both parties under the sets of information and bargaining situation.

The equilibrium of sequential bargaining can be solved through "Backward Induction" method [4]. According to the method, whether a player accepts the counterpart's offer depends on his expectation on the 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.

So, if player A offers the highest price of x_n at the n^{th} round ($n \geq 3$), a loss, L_n^1, may be incurred with the probability of closing the bargaining by player B, thus the expected payoff of player A in the n^{th} round is x_n-PL_n^1. Furthermore, since player B knows that, in the $(n-1)^{th}$ round, any price higher than x_n- PL_n^1 would be accepted by player A, player B's offer in the $(n-1)^{th}$ round should be E-x_n+ PL_n^1. Similarly, for player B, in the $(n-1)^{th}$ round, the expected payoff in the $(n-1)^{th}$ round should be E-x_n+ PL_n^1-PL_{n-1}^2. In addition, since player A understands that, in the $(n-2)^{th}$ round, any price higher than E-x_n+PL_n^1-PL_{n-1}^2 would be accepted by player B, player A's offer in the $(n-2)^{th}$ round should be x_n-PL_n^1+PL_{n-1}^2. Table 2 shows the prices acceptable to player A and player B in the last three rounds as per induced by Backward Induction method.

Table 2. Acceptable prices for player A and player B

Round	Acceptable price for player A	Acceptable price for player B
n-2	x_n-$P\ L_n^1$+$P\ L_{n-1}^2$	E-x_n+$P\ L_n^1$-$P\ L_{n-1}^2$
n-1	x_n-$P\ L_n^1$	E-x_n+$P\ L_n^1$
n	x_n	

Based on the concept of equilibrium, a player cannot produce a better price from the one whoever found at n^{th} round. Therefore, the equilibrium price can only be solved when player A's offer in the n^{th} and $(n-2)^{th}$ round are the same.

$$x_n = x_n - PL_n^1 + PL_{n-1}^2$$
$$\Rightarrow L_n^1 = L_{n-1}^2 \tag{1}$$

3. Determining the JV equilibrium price function

In this research, the expected loss (L_n^k) includes the cost paid for bid preparation plus potential profits in the project. However, the “situation theory” [6] of bargaining suggests that potential profits considered by a player in the bargaining should be the additional profit which can not be gained from other projects. If a player has other opportunities that may earn the same amount of profit, there is no potential profit for this project. Therefore, this research developed a variable, demand for the project (S^k), to encompass the above concept.

Losses expected by player A and player B are as follows:

$$L_n^1 = Bc^1 + (E - y_{n-1} - C^1)S^1 \quad (2)$$

$$L_n^2 = Bc^2 + (E - x_{n-1} - C^2)S^2 \quad (3)$$

Value of S^k is assumed to fall between 0 and 1; the higher the value, the higher the demand for the project, and vice versa. 0 indicates that the player can earn the same profit from other opportunities and doesn’t need this profit at all.

The values (0~1) of S^k are of relative ratio. When player A and player B of the JV team invest in different scales, profits should be shared proportionally. For example, if a construction project requires that player A is responsible for 60% of the total cost while player B takes charge of the rest 40%, then player A who invests more are expected to enjoy a higher amount of profit for the sake of fairness. Thus, the scale of investment should be considered. Player A’s demand for this project should be transformed on the same basis of total profit as player B. Thus, the L_n^k for player A and player B should be:

$$L_n^1 = Bc^1 + (E - y_{n-1} - C^1)(C^2/C^1)S^1 \quad (4)$$

$$L_n^2 = Bc^2 + (E - x_{n-1} - C^2) \times S^2 \quad (5)$$

Substituting (4) and (5) given for L_n^1 and L_{n-1}^2 in (1):

$$[Bc^1 + (E - y_{n-1} - C^1)(C^2/C^1)S^1] = [Bc^2 + (E - x_n - C^2)S^2]$$

$$\Rightarrow x_n = (E - C^2) - [(E - y_{n-1} - C^1)(C^2/C^1)S^1 + Bc^1 - Bc^2]/S^2 \quad (6)$$

Since bargaining between players is a process of offer-counteroffer, and both players tend to gradually lower their offers on the purpose to reach an agreement, when the round of bargaining $n \to \infty$, it can be inferred that the players’ offers will converge, making $x_{n-2}=x_n=x^*$ and $y_{n-3}=y_{n-1}=y^*$.

According to this model, a JV equilibrium price function can be derived by substituting $E = x^*+y^*$ and $E = C^1+C^2+F$ in (6).

$$\Rightarrow x^* = (C^1 + C^2 + F - C^2) - [(x^* - C^1)(C^2/C^1)S^1 + Bc^1 - Bc^2]/S^2$$

$$\Rightarrow x^*S^2 + x^*(C^2/C^1)S^1 = C^1S^2 + C^1(C^2/C^1)S^1 + FS^2 - Bc^1 + Bc^2$$

$$\Rightarrow x^* = C^1 + [FS^2 - (Bc^1 - Bc^2)]/[(C^2/C^1)S^1 + S^2]$$

$$\Rightarrow x^* = C^1 + C^1[FS^2 - (Bc^1 - Bc^2)]/[C^2S^1 + C^1S^2]$$
(7)

In (7), the required cost for bid preparation (Bc^1, Bc^2), execution cost (C^1, C^2), and total profit (F) are already-known values, while demand for the project (S^1, S^2) is not. Thus, fuzzy logic is used to estimate company’s demand for the project.

4. Estimation of company’s demand for the project

A JV party is not difficult to obtain business information and speculate its partner’s “demand for the project”(S). For example, the awareness that the counterpart has not taken any construction project in the last year and opportunities of construction projects will be rare in the following six months suggests that the counterpart's “S” must be high. However, it is always difficult to transform the above information into specific value to facilitate the making of decisions. Therefore, this research incorporated fuzzy logic to quantify the “S” of each party.

Evaluation factors on demand for the project

Carr [7] proposed that a company’s pricing should be considered with its status of business operation. If a company’s returns gained from business operation cannot cover its general and administrative expenditures, this company would suffer from loss. Thus, if a company’s total revenue is expected to fall behind its scheduled revenue target (SR), the company is in an urgent “S” and thus forced to lower its offer for better opportunities. On the contrary, if SR is reached, this company's “S” is relatively low. In this research, the degree of “S” is regarded in terms of the company’s fulfillment of SR. The lower the degree of reaching SR, the higher the company’s “S”. The degree of fulfillment in SR is closely related to received revenues and potential business prospects in the future. Moreover, future revenue is associated with future business opportunities and the level of competition. Thus, three factors, “received revenues”(R), “future business opportunities”(F), and “level of competition”(L), are used to estimate a company’s “S”.

Fuzzy sets and membership functions

Both “R” and “F” are evaluated against the company's degree of fulfillment toward SR. For example, if “R”/SR yields a value of 0.9 (covering 90% of its SR), it is suggested that this company’s “R” is rather high. Both “R” and “F” may exceed SR, so values of these two items range between 0~2 and are further divided into three degrees of “High”, "Moderate", and "Low". As for the variable of "L", the value is represented by "number of competitors", which is the most frequently used criteria for measurement on competition level in previous research. According to the statistics of projects from traffic construction project supervising agencies in Taiwan, the "number of competitors" ranges from 3 to 13, and the average is 7 [8]. Therefore, this research ranges the value of "L" from 3 to 15 so as to include some extremely competitive cases (3 competitors is the minimum requirement for open bids); higher values indicate higher level of competition, which is also divided into three levels of "High", "Moderate", and "Low". "S" is defined in the range between 0 and 1, and further divided into three levels of "High", "Moderate", and "Low".

Membership functions commonly used include triangular functions and bell-shaped functions [9]. To demonstrate the concept more efficiently, triangular functions are used in this research (see Fig. 1).

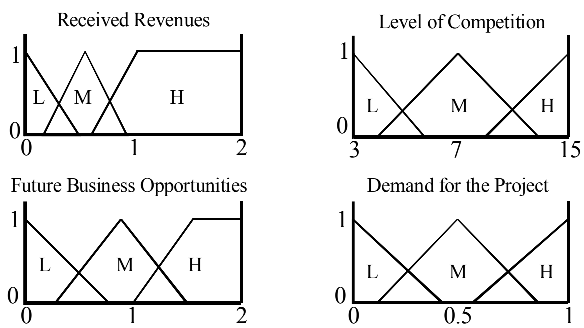

Fig. 1. Membership functions of each criterion and output

The IF-THEN rules

Company's perceptions about the counterpart's demand for the project can be grouped into three rule categories as follows:

- If a company's "R" is high, and: (a) "F" is high, then expected "D" will be low; (b) in other cases, the expected "D" will be moderate.
- If a company's "R" is moderate, and : (a) "F" is high while "L" is low, then the "D" will be low; (b)"F" is not high, then a high "D" is expected; (c) in other cases, the expected "D" will be moderate.
- If a company's "R" is low, and : (a) "F" is high while "L" is low, then the "D" will be moderate; (b) in other cases, the expected "D" will be high.

Twenty-seven If-Then rules are developed based on the conbinations of aforementioned three rule categories (see Table 3.).

Table 3. The fuzzy IF-THEN rules

Rule code		R is		F is		L is		D is
1	IF	High	and	High	and	High	THEN	Low
2	IF	High	and	High	and	Mod.	THEN	Low
...	.	.	.	.	.	.	.	.
27	IF	Low	and	Low	and	Low	THEN	High

5. Conclusions

Bargaining results directly affect a company's revenue and its profit, thus bargaining strategy is crucial to a company's business. This research successfully modeled the bargaining process between companies in a JV construction project and showed that fuzzy logic is a prompt approach to transform a company's mental cognition of ambiguous information into calculable values, enhancing pricing decisions to be more scientific and rational.

In the real JV cases, sometimes bargaining issue is involved with more ambiguous factors than what has been considered in this research. Further researches are encouraged to proceed in this direction.

6. Reference

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