Study on the Game Mechanism of Construction Project Bidding

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Abstract : Construction project bidding is a kind of transaction way of construction project the most widely used ,the bidding is a closed price auction , the game among the bidders and the tenders belongs to a kind of non-cooperation and incomplete static game and so does it among the tenders. According to the special rules of bidding ,the game theory is put into construction project bidding ,the game model of bidding mechanism is set up, the game process of a non-cooperation and incomplete information static is analyzed among the tenders according with the different strategies of tendering price ,the conclusion can be drawn to be applied to construction project bidding ,which can realize “the incentive and compatibility constraints ” and “personal participating in constraints” .Meanwhile, the moral hazard and the adverse selection can be avoided .At last, the great degree of equilibrium and the PARETO optimization can be achieved.

Keywords: the game theory; incomplete information; non-cooperation game; bidding; construction project

1 INTRODUCTION

The game theory was applied to bidding decision at the late 70s,when the researchers of the game theory researched the “auction”. According to the difference of the tender and the payment, the auction can be divided into the following forms: the British auction, the Dutch auction ,the closed and the first price auction, the closed and the second price auction . The closed and the first price auction is the most similar to the rules bidding.

Under this background ,the auction theory was gradually accepted by the mainstream economists ,a lot of game theories and experiments and experience in testing are used as the tools of research. With the rapid development of science and technology ,in terms of construction enterprises ,the success or failure of bidding has become the key of its ability to attract projects and to develop .So the bidding should use advanced theories and methods as its guiding tools as much as possible .The game theory is just a strong theoretical guidance.

In fact ,the bidding system is a game process of non-cooperation and incomplete information among the bidders and the tenders , the different tenders affect other tenders each other ,so the game system has been developed ,which is the theory basis of the game theory applied to the bidding system. At present, most of the owners adopt the rule which the tender who offers a reasonable low price can win the project. After analyzing the basic factor and type , according to the bidding rules ,the game model is built, and the game process is analyzed. At last , the conclusion has been drawn ,which is the game model of bidding can achieve the PARETO optimization and the greatest equilibrium among the bidder and the tenders.

2 THE MAIN FACTORS AND TYPES OF THE GAME

2.1 The basic factors of the game

2.1.1 The concept of game theory. Game Theory is also known as theory of games ,which is the theory and the way of researching a nature of a competition or struggling. and it is a new branch of modern mathematics ,and it’s also an important subject of the operational research.

2.1.2 The basic factors of the game theory .The first factor is the main decision-making .The second factor is the
strategy set, which is the participants’ choices of strategies and action spaces. The third factor is the efficiency which is the participants’ interests [5].

2.2 The game types of bidding

2.2.1 The bidding game belongs to a typical and incomplete information static game. In bidding, the main body of different interests are impacted and affected each other as the decision-making, and they become the parties of a game. Each of the bidders makes their own decision without knowing their rivals’ decision. Therefore, according to their own fact condition and forecasting the entire market and considering other tenders’ bidding strategies, the tender work out the tendering documents which the owner perhaps may accept it. So they can formulate the owners’ acceptable tender, and the tendering documents is sent to the owner or the agent in the closed form. Until all of the tendering documents bid are opened, information of the tenders these information can be known to other tenders and the winner can be determined. Obviously, the above game is a typical incomplete information static game, which will play a very important and practical guidance significance on bidding.

2.2.2 The bidding game belongs to the non-cooperative game. Non-cooperative game is how to choose the strategy of the biggest profits in interactive situation, which is the problem of choosing strategy. In the tendering process, regardless of the number of the tenders there is only one competitor to win the project, so in the meaning, the bidding game belongs to the non-cooperation game[7]. which can be applied to construction project bidding, the greatest equilibrium among the owner and the tenders can be obtained.

3. THE MODEL OF THE GAME THEORY AND ITS’ ALGORITHM

3.1 The conditions of the model of the game theory of construction project bidding

If one project is bid, the bidder would choose the contractor of the lowest price, but from another perspective— the tender’s view, they must face such a choosing when they tender. On the one hand, the lower is the price, the more is the bidder have the probability of winning the project. On the other hand, the cases which the tender can win is known, the lower is the price, the less is the profit of the tenders. We assume that the tendering documents would be the closed and the first price bid, each bidder write down their own price and put it into the envelope, which is sent to the owners or the agents, after the envelope opened, the bidder will choose the tender of the reasonable low price as the successful tender [8].

3.2 the model of the Game of construction project bidding and its’ algorithm.

3.2.1 the model of the Game of construction project bidding. When there are only two tenders in the bidding, a=1,2, let M_a≥0, it’s the bidder a’s price, N_a is the project’s value for the tender a. Assuming that N_a is only known to the tender a himself (because N_a is the tender a’s type), but both the two tenders know that N_a is the uniform distribution function which is defined in region of [0,1] independently. The tender a’s price is as follows[9][10][11]:

$$R_a(M_a,M_b,N_a) = \begin{cases} N_a - M_a, & \text{if } M_a > M_b \\ \frac{1}{2}(N_a - M_a), & \text{if } M_a = M_b \\ 0, & \text{if } M_a < M_b \end{cases}$$  

3.2.2 The algorithm of the model of the Game of construction project bidding. Assuming the price of the tender a is M_a (N_a) which is the strictly increasing differentiable function of its price N_a. Obviously M_a≥1≥N_a, which can not be the best, because no one would like to pay a higher price than the value of the tender to participate in the competitive tendering. Because the game is symmetrical, only do we need to consider the strategy of tendering price of symmetry and equilibrium: M=M*(N)_a. N and M given, the expected price of the tender a is as follows:

$$R_a = (N-M)\pro(M_a<M)$$  

\(\pro(.)\) represents the probability of M_a<M, M_b is the price strategy of the tender b. Because the price strategy is strictly promoting, which is \(\pro(M_b<M) = \pro(M_b\leq M)\). The first item of the function of the tendering price expected (N-M) is the successful tenders’ net income, the second
item of the function \( \text{pro}(.) \) is the Probability of winning.

According to symmetry, \( M_M=M^{*}(N_{\delta}) \), therefore:
\[
\text{pro}(M_0<M) = \text{pro}[M^*(N_{\delta}) \leq M]
\]
\[
= \text{pro}\{ N_{\delta} < M^{*-1}(M) \} = \Phi(M)
\]
(3)

Here \( \Phi(M) = M^{*-1}(M) \) is the inverse function of \( M^* \) (when the tenders select \( M \), \( \Phi(M) \) is their value). After obtaining a final equation, we use a uniform distribution of characteristics (if the \( \theta \) distribution in \([0,1]\) is uniform, all of \( k \in [0,1] \), \( \text{pro}(0 \leq k) = k \)). Therefore, the problems the tenders must face are:

\[
\text{Max} \text{Ra} = (N-M) \text{pro}(M_0<M) = (N-M)\Phi(M)
\]
(4)

The first order conditions of the best optimization is as follows:
\[
-\Phi(M) + (N-M)\Phi(M) = 0
\]
(5)

This is usually the border receipts equivalent to the cost of the boundary conditions (an increasing of the cost of the \( M \) border is that the price of bidding increase \( -\Phi(M) \) (expectations)in the case of setting to win, winning the boundary income is multiplied by the increasing in the probability of winning given the circumstances, the net income \((N-M)\Phi(M)\).

If \( M^{*}(\cdot) \) is the tender’s most optimal strategy, \( \Phi(M)=N \). Therefore,
\[
\Phi(M) = (\Phi(M)-M)\Phi(M)
\]
(6)

The differential equations can be written:
\[
\frac{\partial (N\Phi(M))}{\partial N} = N
\]
(7)

Solutions is:
\[
M^{*} = N/2
\]

That is to say, this game Bayesian balance is each bidder's pricing is half of the real value: \( M^{*}_n = N/2 \). In the balance, the bidders of the highest evaluation of projects is effective from the perspective of the allocation of resources, but the bidders were only half of the tenders value. In contrast, if the information is complete, the competition among the bidders will get all of the value of the bidders.

However, with increasing the number of the tenders, the gap between the tenders price and the actual value decreased. In general, assumption that there are \( n \) bidders, each bidder's value \( N_a \) is independent, the definition in the same interval \([0,1]\) on the uniform distribution, if the evaluation of the bidders for price, his expectations for the pricing function:
\[
R_a = (N-M)\prod_{\text{best}} \text{pro}(M_a < M) = (N-M)\Phi^{-1}(M)
\]
(8)

The first order conditions of the best optimization is as follows:
\[
-\Phi^{-1}(M) + (N-M)(n-1)\Phi^{N-1}(M) = 0
\]
(9)
or
\[
-\Phi^{-1}(M) + (N-M)(n-1)\Phi^{n}(M) = 0
\]
(10)

In the balance because of circumstances, the first order conditions can be written:
\[
-\Phi(M) + (\Phi(M)-M)(n-1)\Phi(M) = 0
\]
(11)

the answer of the equation is:
\[
M^{*}(N) = [(n-1)/n] \times N
\]
(12)

Obviously, \( M^{*}(N) \) is increasing with \( n \) 's increasing. In particular, when \( n \rightarrow \infty \), \( M^{*} \rightarrow N \). That is to say, the more is the bidders, the higher can the bidding price be when the bidders tend to endless, who almost tender value of all the bidders.

### 3.2.3 Analysis on the outcome of game

Game results: the more is the number of the tender, the greater profits can the tender obtain. That is to say, so that more enterprises to participate in the tender, which is a good thing to the bidders. The previous bidding process, the bidders found themselves a few more familiar with the tenders and elected to the successful tender as compared to the relatively low pricing. From the above bidding game analysis can clearly see that because of the different bidders by mastering the different technical level and the other different factors resulted in that some tenders have stronger in this area and other tenders possess the advantages in other aspects. Therefore, the bidders should possibly be invite a large number of the tenders to tender. With raising the number of the tenders, the bidder can also expand the scope considered. The more is the tenders, the more likely do the bidders balance the various aspects.

### 4 CONCLUSION

Based on the characteristics of competitive tendering price, according to the tendering rules, the game model of construction project bidding is built, the game process is analyzed. Based the strategy of equilibrium and the best optimization, the conclusion have been drawn is as follows:
(1) When the strategies of tendering price is the strategies of tendering price of symmetry and equilibrium, the outcome of game is the Bayesian equilibrium game ,which is the bidders only achieve an half of the tenders’ value in cases of equilibrium and incomplete information and non-cooperation .The bidders can obtain whole value of all of the tenders in complete information and cooperation.

(2) The more is the numbers of the tenders ,the tenser is the competition among the tenders ,the tender perhaps may win the project only their tendering quotation is close to the reasonable low price .The anticipators of construction project bidding can apply the method of game analysis to optimize their strategies of tendering ,and make their targets close to the bidder’ s aim ,the PARETO improvement can be achieved among the tenders and the bidders. The bidder can obtain the objective of inviting the tenders of a reasonable low price . At last ,win-win among the bidders and the tenders and construction project management of harmony can be obtained.

5 DISCUSSION

At present, China's construction market is becoming perfect, the bidding will have the more great development. Therefore , how to standardize the bidding has been upgraded to the key and difficult of development. The game theory will be needed to build a new model to solve the various problems in construction project bidding in future. The game theory can really play a great guide of construction project bidding .The medium risk and the strategy of tendering price of equilibrium are analyzed, but the game theory applied to construction project bidding will be needed deeper researching is as follows:

(1)During the bidding process ,the tenders are often come across many accident factors and perhaps have other risk deviations and strategies of tendering price of non-equilibrium and mix-equilibrium ,which will be needed deeper researching.

(2)The types of the risk deviation of the bidders will be researched to be applied to game among the bidders and the tenders ,which the tenders will adopt the greater measure to make decision so as to improve the probability of winning.

(3)After analyzing the strategies of tendering price among the tenders ,the tenders and the bidders ,the game of them will be analyzing deeper, the entire game system of construction bidding will be set up to improve the theory and the practical work of construction bidding.

6 REFERENCES