DOI:
https://doi.org/10.26593/josc.v3i2.7089

Journal of Sustainable Construction
Vol. 3, No. 2, April 2024, 54-61
https://journal.unpar.ac.id/index.php/josc
e-ISSN: 2808-2869 | p-ISSN: 2964-4437

Applying Friedman's Bidding Model Towards Lowest-Bid Procurement Utilizing the Monte Carlo Simulation

Muhammad Irsyad Gandanegara[1]*

Submitted: 13/08/2023 Revised: 30/04/2024 Accepted: 30/04/2024

ABSTRAK
Under the lowest bid procurements, contractors find themselves in a competition in the process of contract bidding. When the rule dictates the lowest price as the contract winner, a high bid value would result in high profits but would have an unlikely chance to win the contract. A low bid would be more likely to win the contract but with lower to no profits. There are methods that solve the uncertainty of optimal bid value, such as Friedman's model which achieves the optimal bid value using bid to cost ratios. Another method is to utilize the monte carlo simulation to model the prediction of the lowest bid for an upcoming projects. The study purpose is to find the optimal bid to cost value of the contractor based on the contractor's past bidding records, the contractor's true bidding cost estimate, and the opposing bidder's bid value. Results show that the optimal bid to cost ratio for known number of bidders ranges from 1,1 for n=1 and 1,02 for n=8 in which n denotes the number of bidders. For unknown number of bidders, the value of the optimal bid to cost ratio is 1,07 with Gamma distribution and 1,08 with rayleigh distribution.

Keywords: bid to cost ratio, first order statistics, Friedman's bidding model, government contracts, Monte Carlo simulation

1. INTRODUCTION

The most common evaluation method for procurement in Indonesia is the lowest bid system. The lowest bid system of procurement creates an environment of close to pure competition, where its main advantage is that it forces companies to lower costs by continuously adopting cost-saving technological or managerial innovations [1].

It is undesirable for a contractor to be in a position where it is less likely to remain in operation, caused by an insufficient number of jobs; hence, overpricing tenders is generally avoided [2]. In competitive bidding, it is also assumed that contractors generally seek the highest expected value.

Under the lowest-bid procurement model, a contractor will attempt to maximize the probability of winning the bid while protecting the interests of company profits for business operational sustainability [3]. However, the uncertain probability of the contractor being the lowest bidder remains challenging as far as seeking the highest value in return.

This issue is pervasive among contractors bidding for procurement in Indonesia, as the current system favors the lowest bid price to determine the winning contractor. In order to build a strategy towards this nature of uncertainty, bid models are developed to utilize historical bidding patterns data in order to formulate the probability of being the lowest bid in the sense of obtaining the optimal expected value in favor of the contractor's interest.

There are various bidding models based on the procurement method, such as Friedman's model, Gate's model, and Ioannou's bidding model. This study intends to apply Friedman's model and implement the Monte-Carlo simulation to evaluate the expected profits and the optimal bid value.

[1] Universitas Katolik Parahyangan, Jl. Ciumbuleuit No. 94, Bandung 40141
* Corresponding Author: 6101801149@student.unpar.ac.id

Journal of Sustainable Construction's License and Permission
Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0)

2. LITERATURE REVIEW

There are various bidding models based on the procurement method, such as Friedman's model, Gate's model, and Ioannou's bidding model. Ioannou & Leu [1] proposed that the low-bid method has possible drawbacks, such as awarding the construction contract at an unrealistically low price, and therefore Ioannou developed a bid model based on the average-bid method. However, the average-bid method is not relevant when the objective is to succeed in a low-bid system procurement.

There are numerous studies implicating Friedman's model applications towards procurements in Indonesia, such as a study done by Yulia et al. [4].Friedman [5] developed a bid model utilizing the theory of probability based on e low-bid method. Friedman's model formulates the probability of winning by analyzing historical bidding records and obtaining a regression equation through curve fitting, thus estimating the probability of winning through the bidding patterns of competitors.

According to Friedman [5], the optimal bidding price can be estimated through the distribution of the true ratio cost as a fraction of the estimated cost. The idea behind using the ratio of actual cost to estimated cost is to determine the bias and variability of the cost estimate. Friedman assumes that every contractor has the same distribution hence introducing the concept of "average bidders".

The opposing bidder's bidding pattern is assumed to behave in the same distribution hence independent and identically distributed, while the ratio of competitor's bid towards the contractor's true cost is assumed to follow a gamma distribution. The model becomes stochastic and hence cannot be solved by a parametric deterministic model. The basic principle of Monte-Carlo simulation is that the input variables are randomized, being described by a certain distribution and will result in a stochastic output following its own distribution [6].

An analytical approach would be too complex to solve this issue, hence the Monte-Carlo Simulation is needed to provide an insight as to the possible outcomes of winning probability when there are two random variables where the ratio of competitor's bid towards the contractor's true cost and the number of bidders follows different distributions. In this study, the simulation will be iterated 10000 times.

3. METHODOLOGY

Data Collection

The data collected will be classified as secondary data in which will also be sourced from government established procurements such as state-owned companies and other governmental institutions. The type of data collected is classified into three types, number of bidders, competitor's bid value, and the contractor's true cost as seen on table 1.

Table 1. Data Sample

Number of Bidders	Opposing Bid		Contractor's True Cost		Government Institution
1	Rp	2.777.592.620,00	Rp	1.966.509.803,92	LPSE
1	Rp	13.667.143.100,00	Rp	11.486.439.773,81	LPSE
1	Rp	8.113.482.729,00	Rp	7.360.796.750,00	LPSE
12	Rp	1.750.138.000,00	Rp	1.966.509.803,92	LPSE
5	Rp	6.152.500.000,00	Rp	5.990.711.009,17	LPSE
36	Rp	731.944.765,89	Rp	738.470.769,93	LPSE
3	Rp	1.160.029.476,00	Rp	1.290.380.000,00	PLN
4	Rp	13.200.000.000,00	Rp	12.932.173.913,04	PLN

Data Analysis
The bid to cost ratio remains the key element towards variable that can be compared toBid to cost ratio refers to the fraction of competitor's bid to the contractor's true cost from past projects. Let B_{ij} represent the Bid of Competitor I from project j and C_{0j} be the contractor's true cost from project j. The bid to cost ratio, X_{ij} is as follows [8].

$$X_{ij} = \frac{B_{ij}}{C_{0j}} \quad (1)$$

$$X_0 = \frac{B_0}{C_0} \quad (2)$$

Each variable X_{ij} and n as the number of bidders possesses their own distribution which will be obtain by curve fitting. In this study, the curve fitting method will be done by a special software that utilizes six model selection criterion method such as Akaike Information Criterion, Bayesian Information Criterion, Average Log-Likelihood, Chi-Sq Statistic, Kolmogorov-Smirnov Statistic and Anderson-Darling Statistic to measure and compare the goodness of fit of every distribution tested towards the data available.

Known Number of Bidders
It is assumed that the upcoming value of n could be estimated through the correlation of the contractor's true cost towards the number of bidders [5]. As previously mentioned, the equation for expected profits when the number of bidders can be estimated is as follows [8].

$$\mathrm{E}(x_0) = [x_0 - 1]\,[1 - (Fx_i(X_0)]^n \quad (3)$$

This equation is based on the assumption that X_{ij} follows a Gamma distribution and $F_{xi}(X_0)$ represents the cumulative probability of possible values of X_{ij} with a lower limit of X_0 and an upper limit of infinity. It is important to note that this equation only applies when the assumed distribution is statistically accepted.

Simulation Modeling
The first step towards running the simulation is to create an output where it expresses the lowest ratio achieved in a random sample that is based on the first order of statistics. It is necessary to define the distribution for each random variable prior to modeling.

$$F_{(1)}(X_0) = 1 - [1 - Fx_i(X_0)]^n \quad (4)$$

Equation 3.4 [8] represents the first order statistics in an open form equation. Since the number of bidders *n* is stochastic and follows a certain distribution, there is no specific set of solutions that can be achieved through the open form equation of first order statistics. $F_{(1)}(X_0)$ is the cumulative density function of $X_{(1)}$ and $Fxi(X_0)$ is the cumulative density function of X_i with a lower bound of X_0 and an upper limit of infinity. The variable *n* represents the uncertain number of bidders opposed towards the contractor. Under this model it is imperative to note that $n > 0$ as the model does not include the lowest sample when there are no bidders as when $n = 0$, this tells us that there are no opposing bidders and the equation will assume that only one opposing bidder remains. $P(X_0)$ is the probability where the contractor's bid to cost ratio X_0 would be lower than $F(x)$. This can be achieved by calculating the right side of the area under the PDF function of the model with the function which is as follows.

$$P(X_0) = RisktargetD(F_{(1)}(X_i); X_0) \quad (5)$$

E(x) [5] represent the expected profits resulted from a certain value of X_0 towards the distribution of *F(x).* The maximum expected profits can be achieved by finding the maximum value of X_0 that has been determined its expected profits. Where *E(x)* is the expected profits, $P(X_0)$ is the probability of being lower than competitor.

$$E(x) = P(X_0) * (X_0 - 1) \tag{6}$$

4. RESULTS AND DISCUSSION

When the Number of Bidders is Known

When it is assumed that information of the number of bidders are known prior to bidding, then the calculation of expected profits becomes simple. The ratio of bid to cost is expected to follow a Gamma distribution while the distribution that the number of bidders follow will not be relevant in this case. The value X_0 represents the contractor's Bid B_0 to cost C_0 ratio, where the mark up is simply just X_0-1. It is can also be interpreted that the lower the contractor bids, the value of maximum expected profits will decrease. Figure 4.1 shows that the greater the number of bidders (n value) then the less likely it is for the contractor to win with a higher bid.

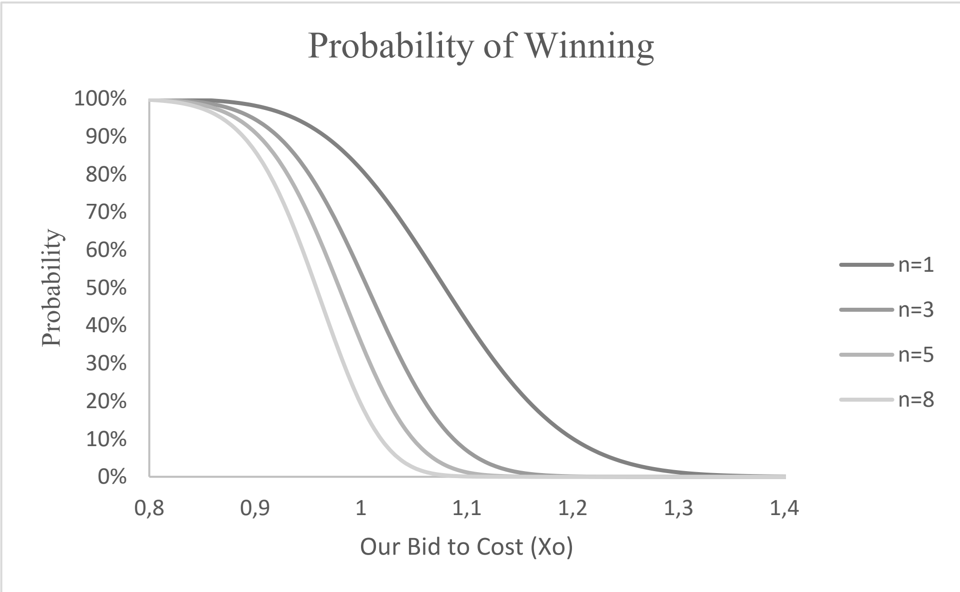

Figure 1. Probability vs Bid to Cost Ratio (X_0)

Table 2 represents the results of expected profits based on the number of bidders and the bid to cost ratio X_0 of the contractor. For every future project with known number of bidders n, to estimate the optimal expected profits is simply a matter of inserting the contractor's ratio X_0 to the probability function 1-$F(x_0)$ that represents the probability that the contractor's ratio is lower, raised to the power of n and multiplied by the profits for said X_0 ratio. The expected value has a global maximum required in order to estimate the optimal expected profits for each number of bidders.

Table 2. Expected Profits

X_0	Number of Bidders (n)			
	1	**3**	**5**	**8**
1,01	0,780%	0,480%	0,290%	0,140%
1,02	1,490%	0,830%	0,460%	0,190%
1,03	2,130%	1,070%	0,540%	0,190%
1,04	2,680%	1,200%	0,540%	0,160%
1,05	3,140%	1,230%	0,490%	0,120%
1,06	3,510%	1,200%	0,410%	0,080%
1,07	3,790%	1,110%	0,320%	0,050%
1,08	3,980%	0,980%	0,240%	0,030%
1,09	4,080%	0,840%	0,170%	0,020%
1,10	4,110%	0,700%	0,120%	0,010%
1,11	4,070%	0,560%	0,080%	0,000%
1,12	3,960%	0,430%	0,050%	0,000%
1,13	3,800%	0,330%	0,030%	0,000%
1,14	3,600%	0,240%	0,020%	0,000%
1,15	3,370%	0,170%	0,010%	0,000%

When the Number of Bidders is Unknown

When the number of bidders become unknown, the problem becomes more complicated as it is not as simple as raising the probability function to the power of n. The number of bidders in this case remains stochastic and cannot be pinned towards one value. The Monte Carlo Simulation is intended to calculate every possible outcome based on the output defined. The n is assumed to have its own distribution that previously was fitted. The number of bidders n random variable follows a negative binomial distribution while the random variable competitor's bid to cost ratio X_i follows a Gamma distribution previously curve fitted with its respected shape and size. After defining the output of the simulation, then simulation is then iterated 10000 times. Figure 4.2 shows the distribution simulation of samples from the first orders statistics simulated.

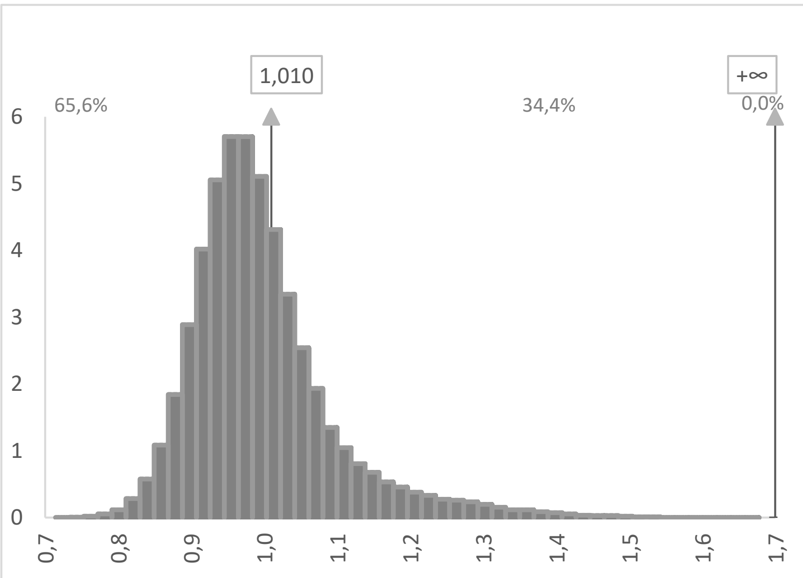

Figure 2. Simulation Distribution

The maximum expected profits for the all the possible values of n occurs at a bid to cost ratio X_0 of 1,07 where the value of the maximum expected profits is 0,960%. Based on Figure 4.6, there is a global maximum expected profit value when the number of bidders remains uncertain or unknown. The value of the maximum expected profit is 0,965% with an optimal bid to cost ratio of 1,06. This tells us that the bid to cost ratio value of 1,07 would have the most profitable result when facing unknown number of bidders.

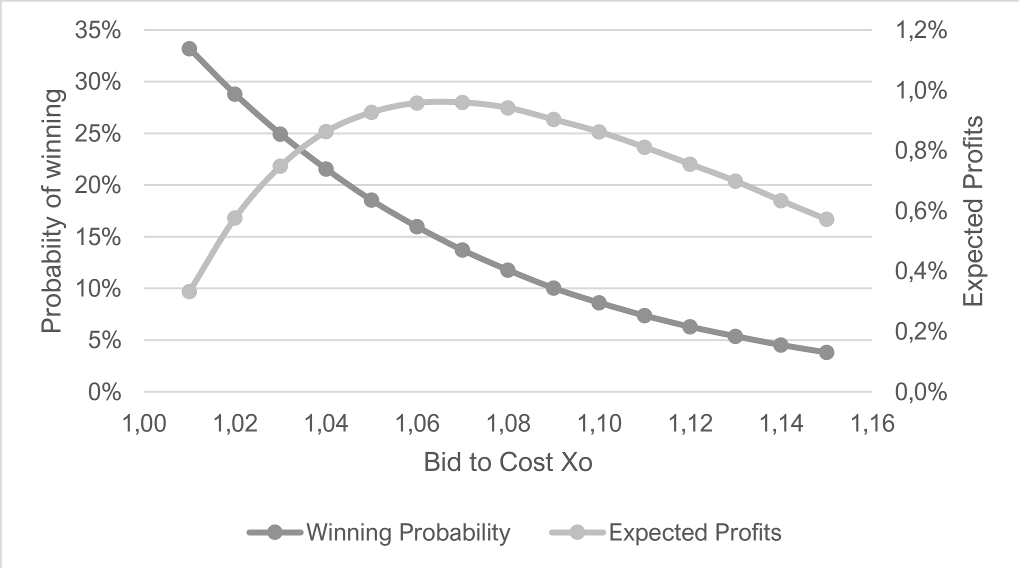

Figure 3. Expected Profits when n is Stochastic

Different Distributions

The Monte Carlo simulation is iterated 10000 times for each different distribution for when n is stochastic, resulting in a probability curve which then will be calculated the probability that each value of X_0 bid to cost ratio is lower. After obtaining the probability, the expected profits will then be calculated based on its X_0 ratio. Based on figure 4.4, It is observed that there is to extent a significant difference of expected profits for different distributions.

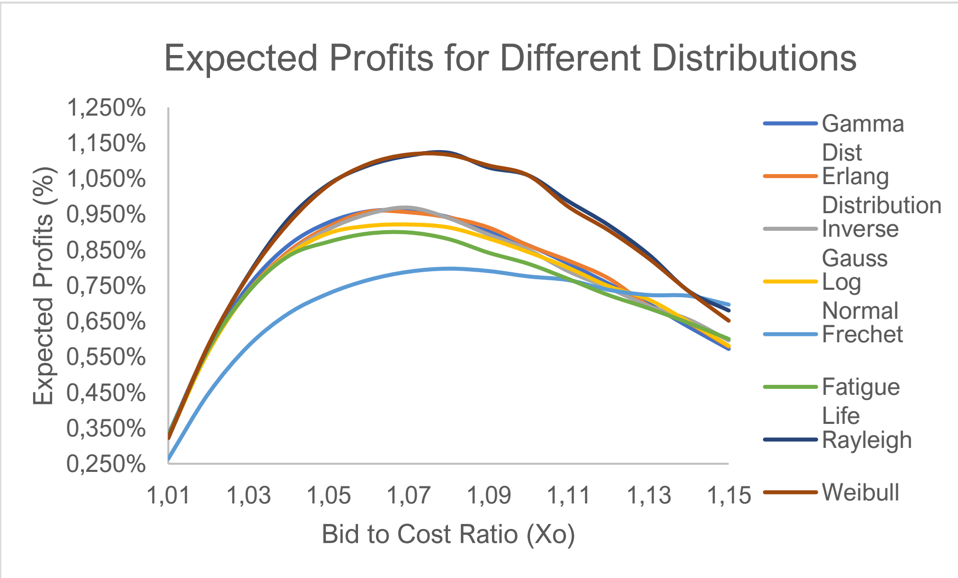

Figure 4.4 Expected Profits of Different Distributions for Stochastic n

After calculating the probability of winning for each distribution when the n value that is stochastic, a table of summary which consists of the maximum expected profits and it's respected optimum value can be listed. Table 4.2 shows that the first four distribution share similar or even the same optimum bid to cost ratio. The value of optimal bid to cost ratio tends to increase as the distribution is less fit towards the data. Past bidding data can have different characteristics and thus different distributions. It is worth mentioning that distributions mentioned do not accurately predict the outcome of bid to cost ratio. It provides insight of how the ratio behaves and works as an approach towards building a strategy towards uncertainty.

Table 3. Optimal Bid to Cost Values for Stochastic n

Distribution	Max Expected Profit	Optimum Ratio
Gamma	0,960%	1,07
Erlang	0,957%	1,06
Inverse Gauss	0,968%	1,07
Lognormal	0,921%	1,07
Fatigue Life	0,899%	1,07
Weibull	1,117%	1,07
Frechet	0,798%	1,08
Rayleigh	1,120%	1,08

5. CONCLUSION

There are various factors which can affect the contractor's mark up, such as the contract size, number of competitors, political factors, management behaviour and other factors that are outside the scope of this study. A greater number of bidders participating creates stronger competition, hence it is less likely to win the contract with significant profits. For unknown number of competitors, it is difficult to determine an absolute value of expected profits hence the need for the monte carlo simulation in which results of expected profit relies heavily on the type of distribution chosen for the monte-carlo simulation. It is important to note that the expected profits are based on probability and does not guarantee actual mean profits. There are other real-life factors that influence the actual profits made and the probability to win such as politics, financial strategy, price fluctuations, unpredictable opponent behaviour and force majeure events. Based on this study's results, the conclusions are as follows:

1) For known number of bidders, the maximum expected profits depend on the number of bidders. As the number of bidders increases, the maximum expected profits inevitably decrease. This means that more bidders present in a certain project causes stronger competition. For unknown number of bidders where the number of bidders is expected to follow a negative binomial distribution and variable X_i follows a Gamma distribution, the maximum expected profits value is 0,960% and the optimal bid to cost value is 1,07.
2) When applying different distributions towards simulating and estimating the probability of winning, expected profits and the optimal bid, a distribution will affect the value of optimal bid significantly, having a difference of value ranging from 1% - 2%.

It is important to note that the scope of this study does not include the optimal bid to cost value based on the independent and identically distributed distributions of competitor's behavior on specific project type and governmental instances. Different governmental instances and project type can have different i.i.d distributions. Further study is needed to expand the optimal value based on i.i.d distribution of specific project instances.

REFERENCES

[1] P. G. Ioannou dan S.-S. Leu, "Average-Bid Method--Competitive Bidding Strategy," *J. Constr. Eng. Manage.,* vol. 119, no. 1, pp. 131-147, 1993.

[2] A. Munns dan K. Al-Haimus, "Estimating Using Cost Significant Global Cost Models," *Construction Management and Economics,* vol. 18, no. 5, pp. 575-585, 2000.

[3] A. Wibowo, "Optimal Bid Price In A Competitive Bidding Under Risk Aversion," *Research Institute for Human Settlements, Ministry of Public Works, Indonesia,* p. 1, 2007.

[4] C. Yuliana, R. H. Kartadipura dan S. Taufik, “Bidding Strategy Using Friedman Model for Building Construction Project in Banjarbaru Indonesia,” *Journal of Civil, Construction and Environmental Engineering,* vol. 1, no. 1, pp. 12-17, 2016.

[5] L. Friedman, “A Competitive-Bidding Strategy,” *Operations Research Group, Case Institute of Technology, Cleveland, Ohio,* vol. 4, no. 1, pp. 104-112, 1956.

[6] V. Platon dan A. Constantinescu, “Monte Carlo Method in risk analysis for investment projects,” *Procedia Economics and Finance,* vol. 15, pp. 393-400, 2014.

[7] A. Wibowo, “Determining reasonable bid ratios under two-sided power distribution assumption for public procurement under capped lowest-cost bidding system,” *Int. J. Procurement Management, Vol. 12(2),* vol. 12, no. 2, pp. 174-198, 2019.

[8] P. G. Ioannou, “Friedman's Bidding Model: Errors and Corrections,” *J. Constr. Eng. Manage,* vol. 145, no. 10, p. 04019058, 2019.

[9] D. Drew dan M. Skitmore, “The Effect of Contract Type and Size Competitiveness in Bidding,” *Construction Management and Economics,* vol. 15, no. 5, pp. 469-470, 1997.

[10] R. I. Carr, “Impact of Bidders on Competition,” *J. Constr. Eng. Manage,,* vol. 109, no. 1, pp. 61-73, 1983.