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Digitalized Probabilistic Approach on Construction Bid Pricing: Case Example of Vietnam

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Abstract

A bidding process is one of the essential phases in any project life cycle, aiming at selecting the proper bidder/tender for the contracted job. The potential bidder expects to win the bid contract by offering the project owner an appropriate bid proposal and significant added value. The literature stops short of comparing the winning probability of construction bids among cost-related factors via exploiting digitalised statistic construction bid database. This paper aims to develop a probabilistic bid pricing approach to determine the probability of winning a bid contract associated with the expected value and standard deviation of the bid price. The paper then analyses the relationship between the winning probability and digitalised cost-related data from a construction bidder's point of view. Those cost-related data include mark-up rate, ratio of a low bid to pre-estimate, and bid-to-pre-estimate comparison rate. Furthermore, in the context of Industry 4.0, the paper applies system thinking in exploiting digitalised construction bid databases from online platforms, showing potential for digital transformation on bid analysis of construction bidders in developing countries, including Vietnam. The finding of this paper, based on the case example of the Vietnamese bidding database, presents that the lower the markup rate, rate of low bid-to-pre-estimate, and bid-to-pre-estimate rate, the higher chance of winning a bid. The paper might be of interest to anyone who is involved in the construction bidding process.

1. Introduction

The bidding process aims to select a qualified, experienced, and competent contractor to implement the construction work on time and within budget [1]–[4]. Generally, the process starts when the project owner develops an invitation to bid (ITB) or request for proposal (RFP), considered questions for potential bidders. Contractors interested in bidding prepare and submit their bids, including technical and financial proposals, based on ITB requirements. Then, the owner evaluates the bids as listed criteria on ITB, such as qualifications, schedule, experience, technical solutions of the bid, and proposed bid price. After negotiation, the contract regulated explicitly on the scope of work, timeline, and payment schedule is awarded to the potential bidder who meets all bid requirements with a reasonable bid price, not just about selecting the lowest-priced bid.

The bid evaluation process in Vietnam's construction sector typically involves initial screening, technical assessment, financial assessment, and contract negotiation. The initial screening provides an overview of all submitted bids to ensure that they meet all listed requirements from ITB. Any bidders who fail to satisfy all minimum requirements are disqualified from the bidding process. In the step of technical assessment, bidders who qualified after the initial screening are evaluated based on the technical capacities and quality of the proposed

solution for ITB. The quoted price from potential winning bidders is analysed and evaluated as the financial assessment step. In the final step, the preferred bidders enter into negotiations to finalise the contract terms and conditions. Generally, bidding selection criteria for construction projects in Vietnam depend significantly on cost, prioritising low-bid contractors unless the proposed low bid is below the direct cost of the pre-bid estimate [5]–[7].

The basic concepts of bidding have been regulated in relatively detailed in the Vietnamese bid regulation system. As per Law on bidding No 43/2013/QH13 which is updated No 22/2023, there are 5 common forms of contractor selection, including open bidding, limited bidding, the direct appointment of a contractor, competitive quotation, and direct procurement [8], [9]. Open bidding refers to the selection process where there are no restrictions on the number of participants. On the other hand, limited bidding is employed when a bidding package requires highly specialised technical expertise or unique technical specifications that can only be met by a limited number of bidders. Other forms, such as direct appointment, competitive quotation, and direct procurement, are applicable in specific circumstances of urgent bidding packages, special cases that involve research, testing, and/or have limited budget resources.

Bidder selection in Vietnam can be done through four commonly used methods: the one-phase with one dossier bag method; one-phase with two dossier bags; two-phase with one dossier bag method, and two-phase with two dossier bags [8], [10]. For one phase with one dossier bag, bidders are required to submit a single bidding dossier that includes both technical proposals and financial proposals in response to the bid invitation. These bid proposals are submitted once and opened simultaneously. In the one-phase with two dossier bags method, bidders have the option to submit two separate dossiers, one for technical and another for financial proposals, as requested of the bid invitation. The bid opening process occurs twice, with the technical proposals being opened immediately after the bid closure, followed by the evaluation of the financial proposal from the qualified bidders. The two-phase with one dossier bag involves the submission and evaluation of both technical and financial proposals (excluding bidding price) during the first phase. Based on this evaluation, a short list of qualified bidders is created, and then the process to the second phase for the final selection of the winning bid. For two phases with two dossier bags, the bidding process is split into two distinct stages. The initial phase involves a comprehensive evaluation and examination of the technical proposals submitted by the bidders. Additionally, the content of the Invitation to Bid (ITB) has also been improved and corrected. Following this, a short list of qualified bidders is created to proceed to the final selection phase.

Approaches to assessing procurement/bidding dossiers, regulated in Vietnamese law on bidding, include (1) the lowest price; (2) the assessment price, and (3) a combination of technical aspects and price [9]. The approach of the lowest price is a procurement assessment approach where the contract is awarded to the bidder who submits the lowest price. This approach is straightforward, focusing primarily on cost as the determining factor for selecting a contractor/supplier. While simplicity is beneficial, it is vital to use this approach judiciously, specifically in situations where the lowest price cost aligns with both the project's objectives and quality standards. The assessment price approach applies to procurements of which expenses may be converted on the basis of technical, financial, and commercial elements for the entire life cycle of goods and services. For bid dossiers that have passed the step of technical assessment, comparison and ranking are based on the assessment prices. The combination of technical aspects and price may apply to procurement where both the lowest price and the assessment price fail to be able to apply. After passing the step of technical assessment, comparison and ranking are based on the overall points score respectively. The bidder with the highest overall points score shall be ranked the first [8]–[10].

A bidder has identified and applied several bidding strategies to get a higher chance of winning the contract. Those strategies can be listed as follows: (1) Low bid, (2) High-tech application and management innovation, (3) Business partnership, (4) Add extra value to the owner, such as a longer-term warranty, unique design, and (5) Sustainable practice and Social responsibility. A low bid, considered one of the most popular strategies, comprises offering high-quality bid services at a lower bid price than other competitors and the pre-estimated level [3], [5], [11]. This paper focuses on strategies for developing a low bid price by calculating the bid-winning chance in relation to digitalised bidding data.

The literature stops short of comparing the winning probability of construction bids among cost-related factors via exploiting digitalised statistic construction bid database, which is the research gap attempted to bridge in this paper. In the context of Industry 4.0, the paper applies system thinking in exploiting digitalised construction bid databases from online platforms, which shows potential for digital transformation on bid analysis of construction bidders in developing countries, including Vietnam. The paper emphasises on relationship between the bid-winning probability and mark-up rate, ratio of low bid to pre-estimate, and bid-to-pre-estimate comparison. The markup rate, emphasised here in this paper, is a rate for the profit of the bid and any other relevant cost over the total direct and indirect costs of the bid. The ratio of low bid to pre-estimate is an average ratio of the proposed low bid price of the bidder to the pre-estimated value from the project's owner. Finally, bid-to-pre-estimate comparison (called price deduction rate) calculated for each bid package is the difference between the proposed bid price and its pre-estimate bid package.

The paper first introduces the bidding process in the Vietnamese construction context and reviews the literature on the non-deterministic approach of bid estimate and assessment. The paper then develops a probabilistic bid pricing approach to estimate the bid price via its expected value and standard deviation (or variance). Next, the probability of winning a bid from the bidders' point of view is analysed considering three components: (1) the markup rate, (2) the ratio of low bid to pre-estimate, and (3) bid-to-pre-estimate comparison. The paper finally applies system thinking in exploiting digitalised construction bid databases from online platforms, which is the potential for the digital transformation of the bidder in any developing country, including Vietnam.

2. Background

The literature on bid pricing is rich. Majzoub and Eweda (2021) conducted surveys and applied a multicriteria selection process using the Analytical Hierarchy Process (AHP) to develop a probability-based model estimating the probability of winning a bid contract with and without BIM involvement in Saudi Arabia. The research's primary objective is to create a probability-based model capable of predicting the likelihood of winning, irrespective of relative weight. However, the examination of Saudi Arabia as a case study demonstrates that integrating a Building Information Modeling (BIM) strategy into the bidding proposal positively influences various tender selection criteria, potentially enhancing the probability of winning bids. Insights from expert interviews indicate that BIM can notably affect specific tender selection criteria, including the cost proposed, facility life cycle and maintenance, management capability, scheduling, and cost control [12].

Faraji et al. (2022) developed regression analysis based on historical data and experts' questionnaires to explore relationships between the contractor's bid decision and proposed mark-ups with the project's characteristics and surrounding bid complexity factors of the petroleum industry in Iran. The research adds to the existing body of knowledge with two key findings: first, by employing the concept of complexity through a Project Complexity Index (PCI) for the tender problem, and second, by simultaneously factoring in both time and cost mark-ups (TMU–CMU) in the contractor's bid. Furthermore, the findings indicate a positive correlation, revealing that as the project complexity increases, so does the bid rate [13]. Farshidpour et al. (2021) introduce a comprehensive statistical model to estimate and assess the accuracy of engineering estimates and bids concerning the final bid price, considering the ratio of bids to engineer estimates. Comparing the outcomes with analogous discoveries in prior research and the efficacy of the methodologies presented, highlighting opportunities for refining statistical analyses of bids and engineering estimates. The conclusions drawn provide project managers with insights to tackle uncertainties in the bidding process, thereby improving the financial sustainability of projects within defined programs. The work concludes, based on an analysis of the bid ratio in the US, bidders often offer their bid price lower than estimated bids [14].

Chao and Liaw (2017) studied a fuzzy logic model to achieve a balance between the chance of winning and loss risk regarding the bidder's position. The paper then represents the minimum overhead-cum-markup rate for a bid by reaching the highest fuzzy score. The findings indicate that the model is capable of distinguishing among bid positions across different scenarios and suggesting consistent minimum bid values [2]. Jaskowski and Czarnigowska (2019) modify Friedman's model to illustrate the impact of correlation on the winning probability and expected markup of a construction bid. The model also determines the optimum markup based on a functional and statistical correlation among the contractor's bid prices [1]. Shrestha and Pradhananga (2010) analysed the impact of competitive bidding on the projects' bid price and found a strong correlation between the lowest bid price and the final construction cost of public street projects in the US. The research identified a robust correlation between the lowest bid price and the final construction cost. Consequently, a regression model was formulated to anticipate the final construction cost of a street project based on the lowest bid price. Validation of the model demonstrated an average prediction accuracy, with the projected project cost typically falling within 3.51% of the actual construction cost [4].

Rahim (2020) used the coefficient of correlation (COC), and hypothesis testing (Z-test for Estimated Cost, Z-test for % Mark-up and T-test) to conclude that the mark-up rate presents less correlation to the win or loss of the contract bid between different sectors. The regression analysis in this paper also indicates that mark-up decreases as the estimated cost increases [15]. Li et al. (2021) analysed leading indicators of the ratio of low bid to owner's estimate associated with risk and uncertainty of construction projects at the cost estimation phase and developed an appropriate multivariate time-series model to predict the ratio of low bid to owner's estimate. The paper might help highway bidders have a comprehensive overview of proposed bid prices and pre-estimates of highway contractors, and lead to acquiring higher accuracy on bid cost estimates for enhancing bid decision-making [3]. Carr (2005) develops a quantitative analysis of the impact of reduced competition on project bid prices and finds out that reducing the number of bidders will result in increased project bid prices. The proposed regression model measures the effects of increased or decreased competition in a robust bidding process. Through regression analysis, it also identifies the characteristics of fluctuating bid activity dynamics, specifically the loss or addition of bidders, revealing a compelling nonlinear relationship [16].

In general, the literature on bid pricing focuses on developing a statistical model to:

- Defining the probability of winning at a particular mark-up rate, ratio of bid price to pre-bid estimate, and bid-to-pre-estimate estimate comparison [1]–[4], [11], [17].
- Defining experimental distribution of competitor's previous bidding decision [14]–[16], [18].

The literature stops short of comparing the winning probability of construction bid among all those relevant factors via exploiting the digitalised statistic construction bid database analysed in this paper.

3. Methodology

A probabilistic bid pricing approach is applied here in this paper to capture any uncertainty related to bid price. Price of construction bid package number i can be estimated as the summation of direct cost (D_i), indirect cost (C_i), and markup (M_i):

$$P_i = D_i + I_i + M_i \tag{1}$$

Where D_i – the direct cost of bid package i, including material cost, labour cost, and equipment cost required for completing construction works of the bid. I_i – the indirect cost of bid package i, which comprises general cost, the home-office overheads in construction site and any cost that has not been estimated from the building design. M_i – markup consists of income for the bidder and any relevant other expenses.

Probabilistic view on the bid price:

$$E[P_i] = E[D_i] + E[I_i] + E[M_i] \tag{2}$$

$$\mathrm{Var}[P_i] = Var[D_i] + Var[I_i] + Var[M_i] + 2.\mathrm{Cov}[\mathrm{D}_i, I_i] + 2.\mathrm{Cov}[\mathrm{D}_i, M_i] + 2.\mathrm{Cov}[\mathrm{I}_i, \mathrm{M}_i] \tag{3}$$

Where the expected value, E[ ], and variance, Var[ ], are established to capture the uncertainty of bid price variables [19]–[25]. Cov[ ] is denoted as the covariance of variables. Direct cost (D_i), indirect cost (C_i), and markup (M_i) can be assumed to be well correlated.

Figure 1 shows an example of advanced system thinking using control systems theory for the Probabilistic bid pricing process, applied in the Vietnamese context. Probabilistic bid pricing, analysed by any bidders, is considered an analysed system, characterised by its input and output, and influenced by disturbance or impact factors [26]–[31]. Input here is all bidder-own internal cost-related data from a bidder, while Impact factors are all digitalised bidding data collected from a third party, such as an online platform which is emphasised in this paper. The fundamental configurations would be analysis, synthesis, and investigation [27], [32]; however, the suitable configuration applied to establish the pricing process should be an analysis configuration: given input and system content (affected by digitalised bidding data), obtain output of probabilistic bidding calculation.

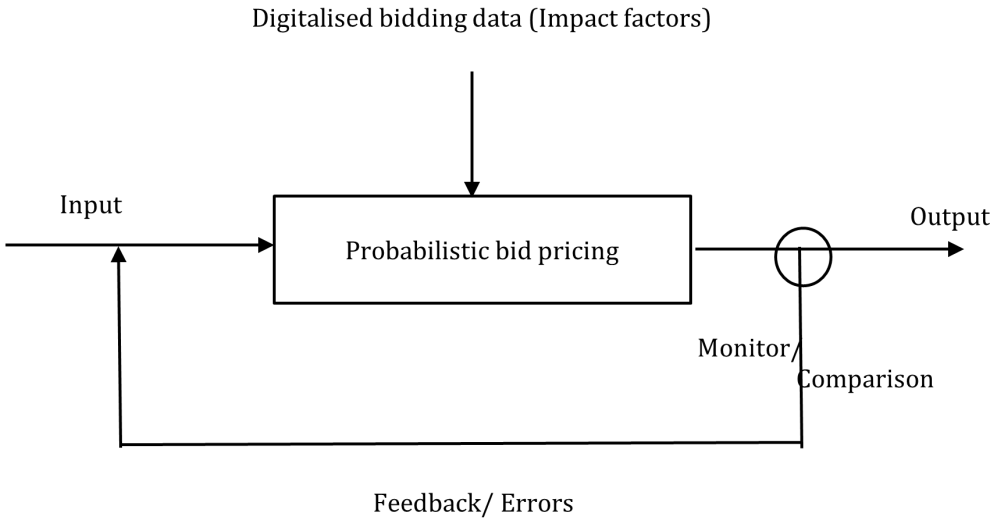

Fig. 1 *Closed loop control (Adapted from [27], [33])*

To start with, measurable and observable inputs that illustrate pricing-related factors should be clearly identified by specific construction bidders. These inputs should be entirely consistent with the bid pricing model, such as historical proposed markup rate, ratio of bid price to pre-bid estimate, and bid-to-pre-estimate estimate comparison, referenced as review results in Section 2. Inputs, including controls and uninfluenceable ones, are also given based on the incorporated bid competitive strategies, such as current business situations of the bidder, competitive advantages in the construction market, and other technical application aspects (for example BIM application). Impact factors or disturbances, for example, availability of historical bidding factor data, forecast changes in construction market demand, and/or government policies, are uncertainties of the external environment. The existence of disturbance leads to a need for a feedback loop, initiating routine, or regular monitoring/comparison. During the continual monitoring process, Vietnamese construction bidders should evaluate the consistency of bid winning probability, and make necessary adjustments. This also improves the system's resilience [34].

The probability of winning bid i, denoted as $P(bid_i)$ is a product of relevant probability components, including the probability of winning at a particular markup rate, ratio of bid price to pre-bid estimated, and bid-to-pre-estimate comparison.

$$P(\text{bid}_i) = \text{P}(\text{W}_m^b < \text{W}_m^t \bigcap \text{W}_r^b < \text{W}_r^t \bigcap \text{W}_{pe}^b < \text{W}_{pe}^t) \quad (4)$$

Where the probability of winning bid at a particular mark-up rate, $\text{P}(\text{W}_\text{m}^\text{b} < \text{W}_\text{m}^\text{t})$, is a winning chance when mark-up rate in bid i ends up less than the threshold of mark-up rate. The probability of winning bid at specific ratio of low bid to pre-estimate, $\text{P}(\text{W}_\text{r}^\text{b} < \text{W}_\text{r}^\text{t})$, is the probability when the ratio of low bid to pre-estimate in bid i ends up less than the threshold of this rate, and the probability of winning a bid in comparing the proposed bid price to the pre-estimate value, $\text{P}(\text{W}_\text{pe}^\text{b} < \text{W}_\text{pe}^\text{t})$, is the probability that the proposed bid price of bid i is below the pre-estimated value.

4. Case Example

The paper cites Truong Son Construction Corporation bidding data as a case example collected from DauThau.info – an online platform database of Vietnam's National construction bidding system. This database was updated in December 2023. As listed in the database, the bidder (Truong Son Construction Corporation) participated in 393 bid packages, including 155 bid/tender invitations and 238 open bidding with a total bid value of around VND 27,163 billion (equivalent to USD 1,139 million). In addition, the paper collects statistical information on markup rate, and ratio of low bid to pre-estimate and analyses the relationship of those cost-related data and the winning probability.

Figure 2 and Figure 3 illustrate the relationship between the mark-up rate and the probability of winning. In general, the probability of winning decreases with the growth of the mark-up rate. Compared to a particular targeted level of mark-up rate of 10%, the probability of winning reaches 80.4%. Noted that the markup rate of 10% is the targeted level for general bids in Truong Son Corporation, and the probability of winning is calculated via an accumulated area of the left-hand side of the 10% markup rate (Figure 3).

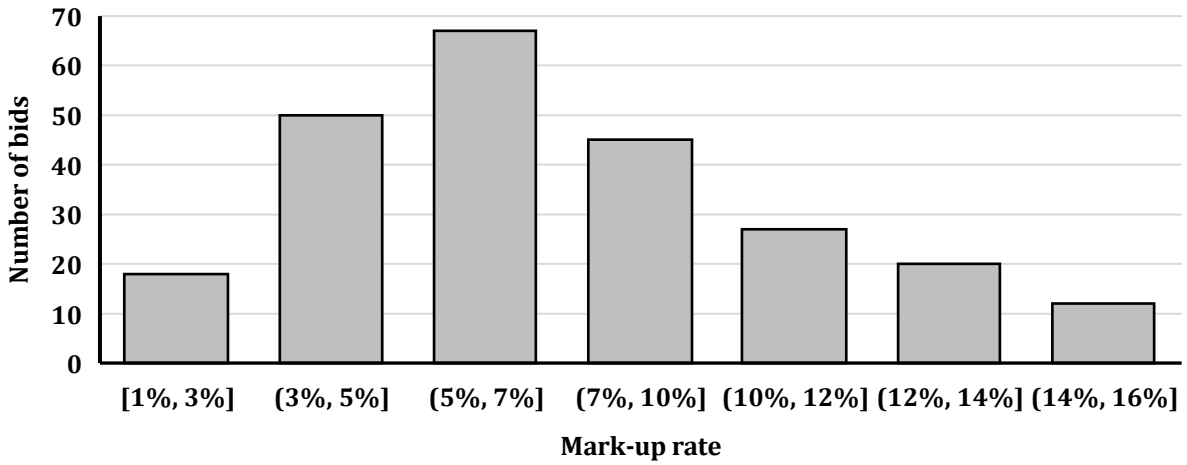

Fig. 2 *Frequency of mark-up rate*

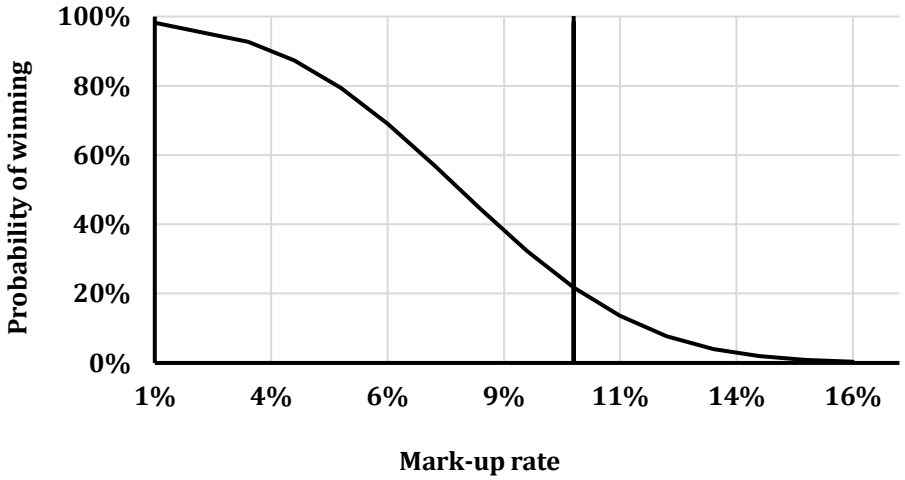

Fig. 3 *Mark-up rate against probability of winning*

Figure 4 and Figure 5 illustrate the relationship between the rate of low bid to pre-estimate (rate of price deduction) and the probability of winning. Generally, the probability of winning decreases with the growth of the rate of low bid to pre-estimate. Compared to a particular targeted level of low bid to pre-estimated (rate of price deduction) of 95%, the probability of winning reaches 79.8%. Noted that the low bid to pre-estimate (rate of price deduction) of 95% is targeted level for general bids in Truong Son Corporation, and the probability of winning is calculated via an accumulated area of the left-hand side of the 95% rate of low bid to pre-estimated (Figure 5).

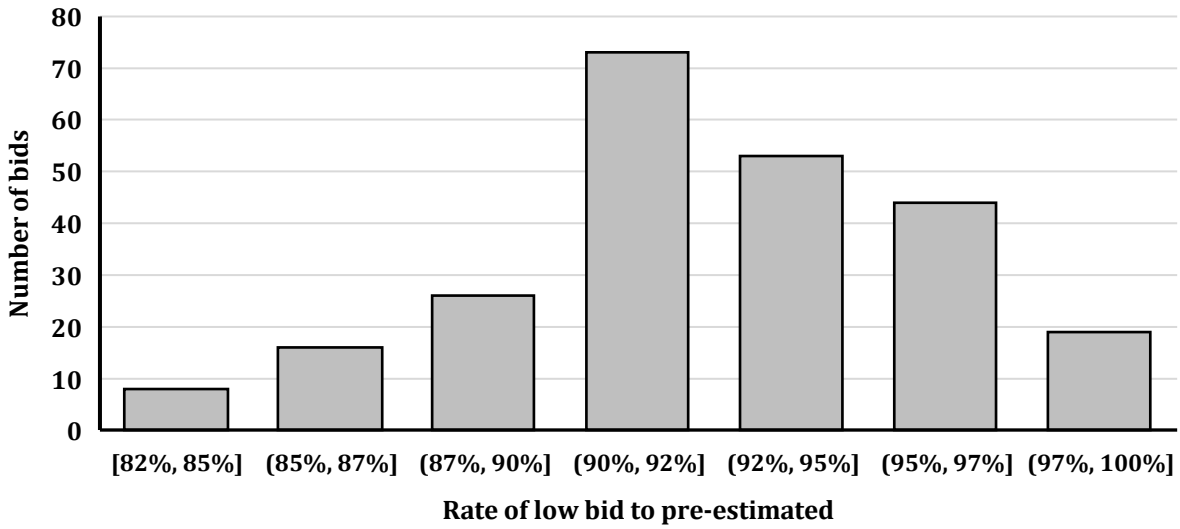

Fig. 4 *Frequency of low bid to pre-estimated rate*

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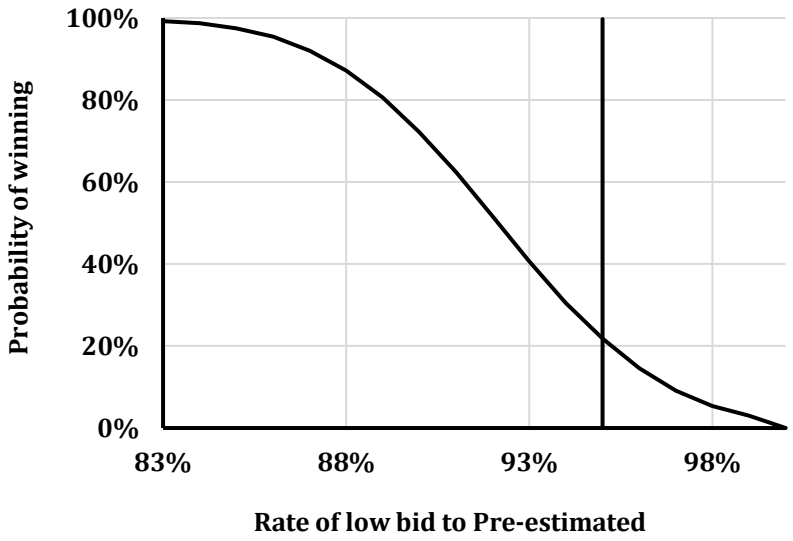

Fig. 5 *Low bid to pre-estimated against probability of winning*

The paper then illustrates a case example of bid package XL6: Construction of tunnel HC1-02 in Project of An Phu intersection, Thu Duc City in southern Vietnam. The project, expected to be completed in 2024, will open the gateway to reduce congestion at the beginning of the Ho Chi Minh City - Long Thanh - Dau Giay expressway and the route to Cat Lai port. An Phu intersection project has three floors: 2-way underground tunnel connecting Ho Chi Minh City - Long Thanh - Dau Giay highway with Mai Chi Tho street (Thu Thiem tunnel side) and the ground path extending through the intersection of Mai Chi Tho - Dong Van Cong. The bid package XL6: Construction of tunnel HC1-02 has a construction cost of VND 463 billion as estimated by the project owner. Based on a calculation of formulas (2) and (3), direct cost (D_i), indirect cost (C_i), and markup (M_i) of the given bid price are assumed to be well correlated and follow a normal distribution, so the expected value of bid price, $E[P_i]$, is VND 342 billion, and its variance, $Var[P_i]$, is (VND 3600 billion)^2.

Figure 6 presents the probability distribution of the proposed bid price.

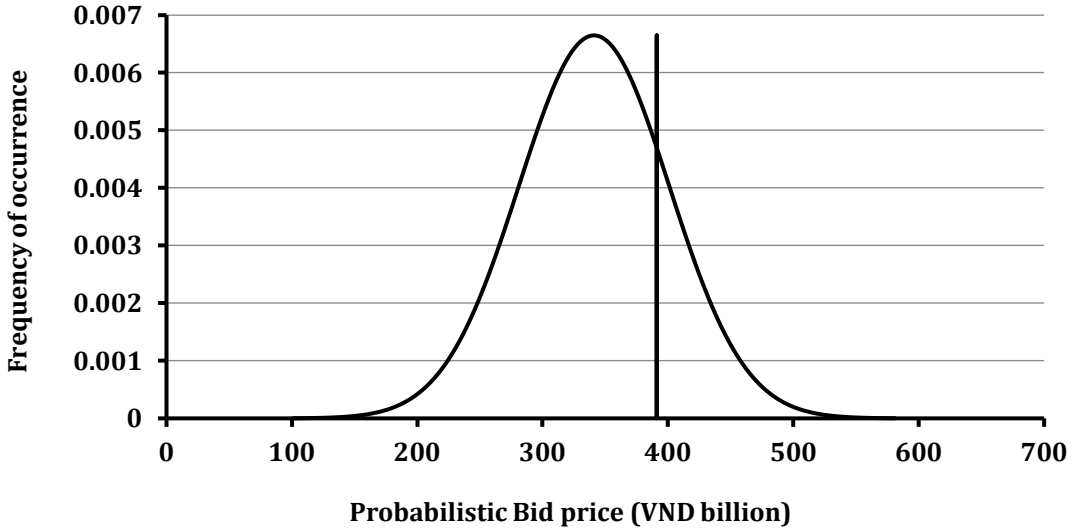

Fig. 6 *Probability distribution of proposed bid price*

Compared to a particular targeted level of the bid price of VND 391 billion (equivalent ratio of low bid to pre-estimate of 85%), the probability of winning can be calculated via an area on the left-hand side of this distribution (Figure 6) which reaches 81.3%. Based on formula (4), the total probability of winning, $P(bid_i)$, is considered as the production of three targeted components, including the probability of winning bid at a particular mark-up rate, the probability of winning bid at specific ratio of low bid to pre-estimate, and the probability of winning a bid in comparing the proposed bid price to the pre-estimate value, reaches 51.6%.

5. Discussion

The paper developed the probabilistic bid pricing approach to calculate probabilistic bid prices. Based on the formula (2) and (3), the expected value E[ ] and variance Var[ ] are used to capture the uncertainty of bid price variables. The probability distribution can be any proposed distribution, based on historical data or any suitable assumption by estimators. However, the normal distribution is preferable.

Advanced system thinking using control systems theory for the probabilistic bid pricing process has been developed and applied in the Vietnamese context. Probabilistic bid pricing, analysed by any bidders, is considered an analysed system, characterised by its input and output, and influenced by disturbance or impact factors. Input here is all bidder-own internal cost-related data from a bidder, such as direct and indirect costs, markup rate, cost reduction rate, and all the above expectations and variance. Impact factors are all digitalised bidding data collected from a third party, such as an online platform which is emphasised in this paper. In the context of Industry 4.0, this systems thinking approach has the potential to analyze digitalized construction bid databases sourced from online platforms.

This research investigates a technique to assess the probability of winning a bid contract by examining digital cost-related information from the perspective of construction bidders. The analyzed data encompass factors such as the markup rate, the ratio of low bid to pre-estimate, and bid-to-pre-estimate comparison rate. These outstanding factors were highlighted in the literature. The two previous factors are from historical data exploited from the online platform, while the final factor comes from a particular bid package. The probability of winning bid is product of all mentioned above probability factors and any proposed factors can be added to model as required by estimators. This approach may develop a suitable calculation of winning bid price and potential/applicable for construction bidding pricing.

The innovative bid pricing approach has the potential to revolutionize bid analysis for construction bidders in Vietnam. The research findings suggest that having lower mark-up rates, low bid-to-pre-estimate ratios, and bid-pre rates increase the likelihood of winning a bid, as substantiated by the case study conducted using the Vietnamese bidding database. This is consistent with the literature.

System thinking on a probabilistic bid pricing model in this paper, based on control systems theory, is suggestive. This can be applied to any bidder in any construction goods and services aspect. The paper introduces, in a broad sense, the fundamental concept of applying system thinking but does not delve deeply into the specifics of the bid pricing process, marking a limitation in its coverage. It is essential to further elaborate on system components, including inputs, outputs, disturbance, and feedback loops, in future research. While these variables may evolve to suit existing circumstances, the core concept of system thinking remains consistent.

6. Conclusion

The bidding process is a crucial stage in the project life cycle as it involves selecting the most suitable bidder/tender for the job. Bidders aim to win the contract by offering a compelling bid proposal and added value. This study explores a method for determining the likelihood of winning a bid contract by analyzing digital cost-related data from the perspective of construction bidders. The data include the markup rate, the ratio of low bid to pre-estimate, and bid-to-pre-estimate comparison rate. In the context of Industry 4.0, the study applies system thinking to analyze digitalized construction bid databases from online platforms, which has the potential to transform bid analysis for construction bidders in Vietnam. The research findings indicate that lower mark-up rates, low bid-to-pre-estimate ratios, and bid-pre rates increase the chances of winning a bid, as demonstrated by the Vietnamese bidding database case study. This paper may be of interest to anyone involved in the construction bidding process. To sum up, the paper contributes to the body of knowledge and practice as follows:

- This paper employs a systems thinking approach to analyze digitalized construction bid databases sourced from online platforms, demonstrating the potential for digital transformation in bid analysis for construction bidders in developing nations, including Vietnam.
- The study investigates the correlation between the likelihood of winning a bid and three key factors: the mark-up rate, the ratio of low bid to pre-estimate, and the bid-to-pre-estimate comparison. The mark-up rate, highlighted in this research, refers to the profit rate of the bid and other relevant costs over the total direct and indirect costs of the bid. The ratio of low bid to pre-estimate represents the average ratio of the bidder's proposed low bid price to the pre-estimated value provided by the project's owner. Lastly, the bid-to-pre-estimate comparison (referred to as the price deduction rate) for each bid package is the variance between the proposed bid price and its pre-estimated bid package.

The future direction of the paper would be taking a deeper survey of the bid pricing database, comparing multiple sources, such as historical internal data of specific bidders, and other technical factors that affected winning probabilities. This research direction expands the complexity of the probabilistic pricing model and any proposed factors can be added to model as required by estimators.

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Conflict of Interest

Author declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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