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Strategy for Mark-up Definition in Competitive Tenders for Construction Work

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Abstract. A competitive tender with the lowest price as the only (or the main) criterion of contractor selection is one of the most common approaches to procurement in construction. On the one hand, it is expected to offer the greatest benefits of competition to the client; on the other hand, it forces numerous competitors to engage time and resources for bid preparation with a low chance to win the job. To stay in the market, the contractor needs to foresee the behaviour of the competitors (which implies knowing who they are and what prices are they likely to offer), and apply some strategy to increase his/her probability to win without compromising the profits. A number of mathematical models of competitive bidding process can be found in the literature, from the earliest basing on probability theory, to more recent that apply artificial neural networks or fuzzy set theory. The paper presents a probability-based method of estimating the optimal bid price (which means a price of maximum expected value of the contractor’s profit) in lowest bid tenders that stems from Friedman’s model (1956). The authors discuss the assumptions that make the model applicable to real-life situations of specialized construction contractors. A worked example based on case-study data is presented to illustrate the idea. To be used in practice, the proposed model has to be fed with up-to-date results of tenders (number of competitors, and their bid prices). The proposed strategy thus rests upon careful monitoring of the market and internal condition of the bidder.

1. Introduction

Competitive tendering in the form of closed-bid auctions is one of the most common procurement routes for construction work. Although frequently criticized as the practice that maintains traditional adversarial relationships among construction project participants detrimental to the sector’s efficiency [1,2,3], it is adopted worldwide by both public and private clients, as well as by contractors wishing to select subcontractors. Competitive tendering requires that the contracting organisation precisely defines the scope and quality of work as well as conditions of contract – in exactly the same way for each bidder, and announces all criteria and assessment methods for the analysis of the bids. Compared with negotiations, the process is believed to be transparent and immune to favouritism [4]. For this reason, it is a preferred mode in public procurement. It is also considered an efficient approach that helps the client make the most of competition: it is viable to compare even large numbers of bids according to a predefined set of criteria, whereas negotiations with numerous bidders would be too time-consuming.

However, from the bidder’s perspective, the more competitors in the tendering procedure, the lower chances to win the job: some statistics suggested that the numbers of tenders won was simply a reciprocal of the number of bidders [5] – so winning were a pure chance. Therefore, cost and effort related with bid preparation is likely to stay without reward, increasing the bidder’s overheads and
reducing profitability. Therefore, the contractors search for strategies to increase their chances to win without compromising their profits.

The authors provide a brief literature review on bidding strategies and bidding models, then present a probability-based method of estimating the optimal bid price in lowest bid tenders that stems from Friedman’s model [6], adapting the original to the estimating practices used in Poland. A worked example based on case-study data is presented to illustrate the idea. The authors then discuss the assumptions that make the model applicable to real-life situations of specialized construction contractors and point to its limitations.

2. Bidding Strategies and Models for Mark-up Definition

A new invitation to tender is a business opportunity. However, a contractors need to follow some bidding strategy in order to engage only if they may be potentially successful in winning contracts at prices which would allow the organisation to carry out the work profitably [7] and reach their organizational goals. A number of bidding strategies have been identified for construction. Tan et al. [8] compiled a set of 13 such strategies of winning jobs:

- Low bid that consist in offering services at prices lower than the competition to increase the chance of winning the contract,
- High-tech that consists in engaging in tenders for complex and demanding jobs where the client searches for expert, and not “cheap” contractors,
- Management innovation, where the contractor may present competitive edge by managing the project in more efficient and original way,
- Joint venture, where the contractor combines forces with partners of skills, resources, and competencies the contractor misses to win demanding contracts,
- Partnership, where the contractor is ready to share profits or losses with other members of the project team,
- Public relation, where the contractor strives to communicate their abilities to the clients and the public so that they are considered the most desired partners for a project,
- Claim that consists in exploiting any mistakes, omissions and uncertainties of the job description and contract conditions to demand more money from the client or other members of the project team,
- Longer term of warranty, where the contractor tries to tempt the client by offering contract benefits other than low price,
- Technology transfer – used if the contractor enters a new market in a developing country and promises to share know-how with locals in exchange for the contract,
- Unique design – used if the contractor offers also design service and promises to better address the client’s needs,
- Risk sharing, where the contractor accepts larger share of risks than their competitors are likely to accept,
- Sustainable practice, where the contractor can promise the client that they are able to deliver the project in more environmentally friendly way than the competitors,
- Social responsibility and accountability.

These strategies can be further blocked into the following groups:

- Strategy of being “cheaper” than the competitors (which often means accepting higher risks, satisfying oneself with lower profits)
- Strategy of exploiting any mistake of the client (this may involve low bidding with the aim to win the job and later recover cost in the course of the project)
- Strategy of offering the client some added value: benefits other than low price.

Assuming a “classic” procurement situation, where the client prepares detailed specification of works and publishes a call for tenders with the main criterion of lowest price, some of the above strategies are
naturally out of question. However, any of them, and regardless of circumstances, requires that the contractor has an insight into identities, numbers, and strategies of their competitors.

The contractors need to decide if to explore an invitation to tender or decline it in search for better options, considering a number of criteria related with job attractiveness, chances to win, production capacities, and current workload related with preparation of other bids [9]. Once the decision to bid is taken, the next issue is to decide on elements of the bid that are going to be subject to assessment. The price stays the key element of the bid and is frequently used as a sole criterion of construction contract award. The price in construction is typically determined as the contractor’s estimate of cost of delivering the work plus risk contingency and profit, the latter often expressed as a fraction of the cost estimate (mark-up) [7, 10, 11, 12].

The literature on determining optimal mark-ups is rich. The optimal mark-up is typically understood as the one that maximizes the expected monetary value of the job [6,13]. The models used in mark-up definitions may be roughly divided into three categories: statistical, multicriteria utility, and artificial intelligence based [14]. Statistical models rely on defining probabilities of winning in competition at a particular mark-up level, with the probabilities defined on the basis of experimental distributions of the competitor’s past bidding decisions [6, 14, 15, 16,17]. As the problem is typically quite complex, and the competitor’s bidding patterns depend on many factors worth incorporating into the model, artificial intelligence (e.g. [18, 19, 20]) or multicriteria utility theory (e.g. [21, 22]) are being employed to capture their relationships. Regardless of their complexity, all these models are fed with data or rules coming from past experience with tenders: number and identity of competitors according to the scale and type of the work in question, and the conditions (including prices) they offered.

3. Friedman’s Model of Bidding Strategy

Let us assume the perspective of a bidder, $A_0$, who decided to participate in a tender procedure where they compete with $n$ other bidders, $A_1, A_2,…, A_n$ (their number and identity is assumed known in advance). Let $c_i$ represent the cost of delivering the work (both direct and indirect) estimated by bidder $A_i$, and $b_i$ – the corresponding bid price offered by bidder $A_i$ ($i=0, 1,…, n$).

Each bidder $A_i$ estimate their cost to be $c_i$ and are to decide on the bid price $b_i$. The cost cannot be treated as a deterministic value, as the estimates rest upon certain assumptions on the most likely prices of resources, productivity levels of the workforce, physical conditions of works, etc. The cost estimate is thus a projection based on past experience and information on current situation. To turn the estimate into the bid, a mark-up ($m_i$) needs to be added, allowing for the bidder’s general overheads and profit. Thus, the bid of each competitor $A_i$ can be expressed by the following formula:

$$b_i = c_i + m_i. \quad (1)$$

Let us assume the Polish style of presenting cost plans and bids in public tenders in terms of elements of the bid price (direct and indirect costs, profit). It follows the industry’s best practices [11]. It was translated to regulations on the methods of preparing the client’s estimates, and is frequently enforced on the bidders if they are to supply a detailed priced bill of quantities, so naturally affects the way they prepare their estimates and offers [23]. According to these guidelines, the cost comprises direct costs, $c_i^d$, and all indirect costs, $c_i^{ind}$:

$$c_i = c_i^d + c_i^{ind}. \quad (2)$$

The direct costs are composed of cost of materials $c_i^M$ (that include buying costs), cost of labour $c_i^L$ and cost of plant $c_i^P$:

$$c_i^d = c_i^M + c_i^L + c_i^P. \quad (3)$$
All indirect costs (combined preliminaries, project-specific overheads, and general overheads) are often required to be expressed as a fraction of direct labour and plant cost:

\[ c_{\text{ind}}^i = w_{\text{ind}}^i \left( c_{\text{L}}^i + c_{\text{P}}^i \right), \tag{4} \]

where \( w_{\text{ind}}^i \) stands for the preliminaries and overhead ratio calculated by bidder \( A_i \).

Profit \((m_i)\), according to Polish estimating guidelines [11] as well as industry practice [23], is most frequently expressed as a fraction of the sum of direct labour, direct plant and total indirect costs:

\[ m_i = w_{\text{m}}^i \left( c_{\text{L}}^i + c_{\text{P}}^i + c_{\text{ind}}^i \right) = w_{\text{m}}^i \left( c_{\text{L}}^i - c_{\text{m}}^i \right), \tag{5} \]

The symbol \( w_{\text{m}}^i \) represents the ratio of profit applied by bidder \( A_i \) to complete the tender. Considering formulas (1) – (5), the ratio of profit can be expressed as:

\[ w_i = \frac{b_i - c_{\text{m}}^i}{c_{\text{L}}^i - c_{\text{m}}^i} - 1 \tag{6} \]

Bidder \( A_0 \) does not know the bid prices \( b_i \) of the competitors in a tender that has not been concluded yet, and it is unlikely that he/she gets access to the competitor’s cost estimates \( c_i \). Friedman [6] decided that, from the point of bidder \( A_0 \), they can be treated as random variables (as such, they are going to be referred to as \( C_i \) and \( B_i \) later in the text), despite the fact that from the point of the competitors \( A_1, A_2, \ldots, A_n \) who calculate them, they are decision variables. Similarly, from the point of bidder \( A_0 \), other bidders’ profit rates may be considered random values \( W_{i}^{m} \) \((i = 1, 2, \ldots, n)\).

The Friedman’s model of tender strategy [6] is based on the following assumptions:

- \( W_{i}^{m} \) are independent random values;
- Distributions of \( W_{i}^{m} \) are independent from the decision of bidder \( A_0 \) on their profit rate \( w_{0}^{m} \) and their cost estimates \( c_0 \) (including material cost).

The types and parameters of \( W_{i}^{m} \) distribution can be estimated on the basis of historic records of tenders with participation of bidders \( A_i \). It is likely that the only basis for bidder \( A_0 \) to prepare such estimates is information on total bid price of their competitors (as it is announced to all bidders), without any idea of the competitor’s true cost estimates. Therefore, the historic profit rates of the competitors estimated by the contractor \( A_0 \) can only be “standardized” according to costs estimates of bidder \( A_0 \) by means of the following formula:

\[ W_{i,k}^{m} = \frac{b_{i,k} - c_{0,k}^{M}}{c_{0,k}^{L} - c_{0,k}^{M}} - 1, \quad i = 1, 2, \ldots, n, \quad k = 1, 2, \ldots, s, \tag{7} \]

where:
- \( W_{i,k}^{m} \) – estimate of standardized profit ratio used by bidder \( A_i \) in tender procedure \( k \), prepared by bidder \( A_0 \) on the basis of \( A_i \)’s bid price (announced) and \( A_0 \)’s cost estimates for the same tender,
- \( b_{i,k} \) – bid price offered by bidder \( A_i \) in tender procedure \( k \),
- \( c_{0,k} \) – total cost of works estimated by bidder \( A_0 \) in tender procedure \( k \),
- \( c_{0,k}^{M} \) – direct cost of materials estimated by bidder \( A_0 \) in tender procedure \( k \),
- \( s \) – number of historic tenders providing insight into the competitors’ behaviour.

Standardization of profit rates as in equation (7) makes sense only if the structure of cost in the analysed tenders is similar (i.e. the proportions of direct and indirect costs), and if the cost estimates of
different competitors are comparable. Such circumstances are characteristic for specialty contractors active in the same market. They rely on the same suppliers, use similar construction methods. Their competition in the same market leads to levelling their production costs.

The profit \( V \) of bidder \( A_0 \) is a binary random variable that assumes two values: either \( m_0 \) with the probability \( P(win|w_0^m,n) \), so the probability of winning in competition with \( n \) other tender participants with the profit rate decided to be \( w_0^m \), or 0 with the probability of \( 1-P(win|w_0^m,n) \), so the probability of losing in competition. The optimal decision on the value of the profit rate, \( w_0^{m,*} \), maximizes the expected value of the contractor’s profit:

\[
\max E(V) = P(win|w_0^{m,*},n)(c_0 - c_0^M)w_0^{m,*},
\]

and \( w_0^{m,*} \) corresponding to the extreme value of profit can be found by solving the following equation:

\[
\frac{dE(V)}{dw_0^m} = P(win|w_0^m,n)(c_0 - c_0^M) + \frac{dP(win|w_0^m,n)}{dw_0^m}(c_0 - c_0^M)w_0^m = 0 ,
\]

Therefore:

\[
w_0^{m,*} = -\frac{P(win|w_0^{m,*},n)}{dP(win|w_0^m,n)} w_0^{m,*}.
\]

The probability of bidder’s \( A_0 \) winning the tender with a particular value of \( w_0^m \), so their price being lower than the prices offered by any other competitor, can be calculated according to the following formula [24]:

\[
P(win|w_0^m,n) = P(W_1^m > w_0^m) \cdot P(W_2^m > w_0^m) \cdot \ldots \cdot P(W_n^m > w_0^m) = \prod_{i=1}^n [1 - F_i(w_0^m)],
\]

where \( F_i(w_0^m) \) stands for the distribution function of the random value of \( W_i^m \), and \( n \) is the number of competitors.

The authors of [6] and [24] presented a recurrent algorithm for providing an approximate solution of equation (10) under assumption that all \( W_i^m \) are of normal distribution of the same parameters. However, using standard office spreadsheets, one can prepare graphs illustrating relationship between the probability of winning and the expected value of profit rate for any distribution types of \( W_i^m \).

4. Example

This section presents the method for estimating the optimal profit rate for calculating bid price for a particular contractor specialized in external thermal insulation works. The contractor participates in tenders organized directly by private clients, mostly housing estate facility managers. The bid assessment criteria varied tender to tender, but lowest price was always the key one, with the other being a formality, as the bidders proposed exactly the same conditions in their respect. The example is based on data on 20 historic tenders of their three most active competitors from the period 2014-2018. As the example concerns a company that operates locally, the number and identity of bidders are assumed to be certain.
Table 1 presents, as example, one record from the input sample of tender data to be used for estimating distribution parameters of the competitors’ standardized profit rates, $W_i^m$. It comes from one of the tenders for insulation work in a multifamily block, where the bidders were to compete by all-in unit price of total works per square meter of the façade. The table presents prices of three competitors $b_i$, the total cost of work $c_0$ and the material cost $c_0^M$ estimated by the analysed contractor, and the estimates of standardized profit rates of the competitors calculated according to equation (7).

| Competitor 1, $i=1$ | Competitor 2, $i=2$ | Competitor 3, $i=3$ |
|---------------------|---------------------|---------------------|
| $b_i$               | 48.25               | 48.20               | 48.40               |
| $c_{0,i}$           |                     | 45.36               |                     |
| $c_{0,i}^M$         |                     |                     | 17.93               |
| $w_i^m$             | 0.105               | 0.104               | 0.111               |

For recorded tender data, the hypothesis on the empirical distribution of the competitor’s profit rates $W_i^m$ being normal was not rejected by standard normality tests (Shapiro-Wilk, Kolmogorov-Smirnov).

The profit rates were thus assumed to be of normal distributions and the following parameters:

- $W_1^m \sim N(0.103;0.013),$
- $W_2^m \sim N(0.097;0.011),$
- $W_3^m \sim N(0.105;0.009).$

Figures 1, 2, and 3 illustrate, correspondingly, the relationships between the profit rate and the probability of winning, between the profit rate and the expected value of profit divided by costs excluding material costs, and between the probability of winning and the expected value of profit divided by costs excluding material costs.

![Figure 1. Profit rate against probability of winning](image1)

![Figure 2. Profit rate against expected value of profit relative to costs](image2)

![Figure 3. Probability of winning against the expected value of profit relative to costs](image3)

Quite naturally, the probability of winning drops with the growth of profit rate (figure 1). In this particular case, the optimal choice of profit rate is 0.078 as it provides the bidder with the maximum
expected value of profit relative to cost (figure 2), with a corresponding probability of winning being 0.93 (figure 3).

5. Discussion and Conclusions
As illustrated by the example, application of Friedman’s model is computationally straightforward. If the user is able to collect enough data on prices offered in past tenders by his/her competitors (and this is easy as the bid values are announced to all tenderers), the competitors’ profit mark-ups can be estimated relative to the user’s costs and thus standardised – expressed independently from the actual proportion of the competitor’s bid price (known) and estimated costs (unknown). On this basis, the competitor’s “bidding profile” can be created in the form of defined probability distributions of their standardised mark-ups. Assuming that each competitor’s bidding decision in the coming tender is going to follow this pattern, the user is able to calculate his/her price in a way that maximises the expected value of the user’s profit – which can be done without any sophisticated software.

However, the model rests upon a number of assumptions that are not automatically true in the practice of construction contracting. First, the model assumes that the competitor’s mark-ups follow some particular probability distribution – this assumption has been questioned by a number of researchers. As economic conditions change (e.g. due to fluctuations of resource prices and business cycles in construction), and the competitors themselves change (e.g. diversify economic activities), the competitors’ “bidding profiles” evolve over time, and capturing them in the form of an experimental probability distribution compiled on the basis of a historic sample from an arbitrarily defined period may be a too far going simplification [25].

Second, the model assumes that the competitors’ mark-ups are mutually independent random variables. This ignores the impact of factors that affect pricing decisions of all competitors in a particular market.

Third, the model assumes that the user is able to predict how many competitors, and exactly who of them, are likely to participate in the tender procedure. In the highly competitive construction market, contractors always search for opportunities and often bid outside their local markets. It is therefore a risky assumption; proposals how to deal with these problems were given already by Friedman (introducing a notion of an “average” bidder, and trying the number of bidders as a random value of Poisson distribution) [6], as well as many other researchers [26].

To sum up, the model oversimplifies many aspects of business. Nevertheless, in some cases (specialty contractors active only locally), this model may have some merits. Its practical application relies on introducing a monitoring system for all tender procedures a particular contractor is likely to participate to adapt the model parameters to changing conditions.

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