Pricing Strategy for Best Value Tender

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Abstract: Unlike the traditional price-focused lowest bid (LB), the best value (BV) tendering process selects the contractor that offers a product or service that is most beneficial to the procurement entity in various aspects. Existing pricing models, including cost-based probabilistic models and market-based neoclassical microeconomic theory, were developed for LB. Very few operational models exist for BV tenders due to the difficulty of measuring the price differences with respect to the variance of product or service quality. This paper proposes a price elasticity of quality (PEQ) model that provides useful tools to measure the PEQ of a product or service offered by contractors in a tendering process. Based on the proposed model, a bidding zone is suggested for the contractor in light of competitiveness and profitability. Two working examples are used to show the applicability of the proposed method. DOI: 10.1061/(ASCE)CO.1943-7862.0000635.

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Introduction

Tendering of project-type works has been highly competitive due to the nature of one-off price determination with sealed bids (Raneson and Skitmore 1999; Skitmore 2004). The system of tendering was designed and established intentionally by procurement entities to form a competitive situation where bidders do not have any pricing information of other competitors and only the bidder offering the lowest bid wins the award. As a result, competitive bidders tend to lower their bidding prices in order to win the bid, and the procurement entity obtains the lowest price of the product or service. This kind of traditional lowest bid (LB) tender selection method may result in a low price. However, low-priced products or services may not meet the quality requirements of more complex modern projects. Therefore, a different tender selection process, called best value (BV), was introduced to improve the drawbacks of the traditional LB in procuring a higher quality product or service.

The BV refers to the optimum outcome of a business process (Akintoye et al. 2003). The value of a BV tender includes tangible, intangible, intrinsic, and extrinsic aspects of evaluation. Time, cost, image, aesthetics/appearance, operation and maintenance, managerial safety, and environmental aspects are possible quality-related elements of the BV (Gransberg and Ellicott 1997). In contrast to LB, the BV emphasizes quality, efficiency/effectiveness, value for money, and performance standards (Akintoye et al. 2003). It aims at enhancing long-term performance through a selection of the contractor that is most advantageous to the procurement entity while price and other factors are considered (Abdelrahman et al. 2008). When bidders compete with each other under the BV approach, the quality differentiation strategy offering the most value to the procurement entity with the preferred price will finally determine the probability of winning a bid (Perng et al. 2006). The nature of BV tenders significantly impacts the competition of bidders in tendering. It shifts the competition from simple (price) to heterogeneous (multicriterion) competition (Friedman 1956; Wong et al. 2000).

Existing models have been suggested for improving the pricing requirement of LB tendering. Generally, they are classified into two categories (Ngai et al. 2002; Skitmore et al. 2006): probabilistic models (Friedman 1956; Gates 1967) and neoclassical microeconomic theory (Hillebrandt 1974). The former was first proposed by Friedman (1956) and Gates (1967) in their early publications. They were called by Skitmore et al. (2006) the full-cost pricing method since the pricing strategy was basically the recovery of the cost required to manufacture the product (or perform the service) plus a satisfactory profit. The latter is established under an assumption that there is a perfectly competitive market, where no one firm (either procurement entity or contractor) is dominant (Ngai et al. 2002). As a result, the pricing of the tender reaches equilibrium at the point where the curves of demand and supply intersect. Both of the aforementioned pricing models have assumed a homogeneity of the product or service offered by the contractor (Ngai et al. 2002). Such a homogeneity assumption may not lead to accurate pricing under a system of BV tendering.

Originally, the BV tendering method was introduced to solicit contractors with specialized expertise in performing specific types of projects. Subsequently, it was discovered that BV results in higher-quality work much more efficiently (Perng et al. 2006). According to the published data of the Ministry of Justice (MOJ) of Taiwan, the percentage of BV tendering in public procurement projects increased from 3.61% in 2001 to 12.18% in 2005 (MOJ 2009). Facing the increased popularity of BV tendering, bidders are considering an essential problem: how much money should be submitted as the tender price for a specific tender? Unfortunately, there is no existing model in the literature.

To answer and resolve the foregoing question, it is necessary to understand the nature of a BV tender. The original concept of BV stemmed from the idea that one contractor offers a better quality
(measured by multiple criteria) product or service than other contractors. Indeed, the quality foundations of different contractors are not equal. Therefore, instead of asking for the lowest price, the procurement entity would rather obtain a higher-quality product or service in exchange for a higher price. Under such a consideration, there is a tradeoff between the monetary value (price) and the utility value (for better quality). In this regard, some models have been developed and established on a time/cost tradeoff approach (Herbsman et al. 1995; Shen et al. 1999). However, a general model for pricing BV tenders has not yet been developed. This paper aims at developing such a model to assist BV contractors in pricing their tenders much more competitively and profitably.

Tender Pricing Models Revisited

The most extensively researched tender pricing model is probably the one proposed by Friedman (1956). In that model, Friedman estimates the probability of winning a bid as a function of the profit rate (represented as a percentage of the estimated cost). The distribution of the function can be constructed based on the competitors’ bidding price information that the bidder has encountered in the past. It is naturally inferred that if the contractor assigns a higher profit rate, it will be resulted in a lower winning probability. Therefore, the optimum tender price is the one that results in maximum expected profit (MEP) (Friedman 1956). A different model, however, using the same underlying assumption in estimating the function of winning probability was proposed by Gates (1967). As pointed out by Runeson and Skitmore (1999), the major difference of the two aforementioned models lies in the fact that the Friedman’s model provides a tender pricing strategy for a single bid, while Gates turned it into a general theory for tender pricing. Since then, numerous researchers have followed Friedman’s and Gates’ models or developed their own, all trying to determine which one is correct (Benjamin 1972; Carr 1982; Crowley 2000; Dixie 1974; Engelbrecht-Wiggans 1980; Griffis 1992; Ioannou 1988; Skitmore 2002, 2004; Skitmore et al. 2007). Among those researchers, Carr’s (1982) and Skitmore’s (Skitmore 2002, 2004; Skitmore et al. 2007) models are probably the most important after Friedman’s and Gates’. Regardless of which of the preceding models is considered, the essential concept of the tender pricing of these probabilistic models lies in the recovery of the cost required to fulfill the contract plus a certain profit percentage. It can be considered a cost-based model. In this regard, two important attributes for building a cost-based model are the estimated cost for fulfilling a contract and the a priori probability function of winning the bid given a specific profit rate.

A second category of tender pricing model comes from neoclassical economics, that is, neoclassical microeconomics (Hillebrandt 1974; Ngai et al. 2002; Runeson and Rafterty 1998). This model is also established under an assumption that there is a perfectly competitive market. The pricing of a product or service in the market is a result of a compromise between the demander (procurement entity) and the supplier (contractor) in the market. Models in this category can be considered market-based models. With a market-based model, the market price is that price at which the supply of an item equals the quantity demanded. Such an economic equilibrium can be dynamically relocated due to the imbalance of various economic forces, for example, as a surplus in demand or supply emerges. Eventually, a new equilibrium will result and a new market price will be established (Skitmore et al. 2006). The neoclassical microeconomics pricing model assumes that no single player, neither buyer nor seller, in the market can individually affect the market price, that is, individual buyers and sellers are too small a part of the total market to affect market prices (Ngai et al. 2002).

Essential Heterogeneity of Best Value Tendering

The tender pricing models reviewed in the previous section assumed a homogeneity of contractors (Ngai et al. 2002; Skitmore 1991), i.e., the competition among the contractors is simply their offered prices. This is also the underlying assumption behind the original model of Friedman, where he assumed the probability of winning a bid is a function of the bidding price (Friedman 1956). However, such an assumption does not hold in a real-world market, as pointed out by Runeson and Skitmore upon a thorough review of the existing tendering models (Runeson and Skitmore 1999) and several subsequent works (Skitmore 1991; Skitmore et al. 2007; Skitmore and Smyth 2007). Recent studies conducted by Oo et al. (2008, 2010) in their comparison of contractors in Hong Kong and Singapore also showed strong evidence of heterogeneity in bidders’ decisions (both for to-bid and markup) regarding the same tendering conditions. Oo et al. (2008) discovered, with a random-coefficient logistic model, that there exists significant heterogeneity in bidding decisions across bidders in Singapore and Hong Kong. However, their model does not support the pricing of BV tenders in light of the heterogeneity of bidders. As a result, they concluded and suggested that future bidding models in construction should concentrate on individualized models that reflect the specific strategies adopted by contractors, taking into account factors of heterogeneity.

The notion of heterogeneity has been considered in many areas including biological, medical, economic, marketing, and organization behavior studies (Chamberlin 1933; Chintagunta et al. 1991; Jain et al. 1994; Verbeke and Lesaffre 1996), but not until recently in the construction industry and procurement tendering (Oo et al. 2008, 2010). The heterogeneity of bidders’ decisions to bid or markup is essentially due to the difference in capabilities, management skills, and experiences among bidders in performing the same types of projects (Gonzalez-Diaz et al. 2000; Oo et al. 2010). Chamberlin (1933) defined heterogeneous products as products that “pose obvious characteristics that can differentiate each other.” Scherer (1980) stated that the heterogeneity (of procurement) is “the different quality of the product that causes difference in the conception of the consumers and reaches equilibrium of price in the market.” Combining both of the preceding definitions for a BV tender yields the following statement: “heterogeneity is the different quality (conceived by consumers and measured by a set of predefined selection criteria) of work to be performed by contractors (in a competitive bid) that reaches equilibrium of price in the market.” The quality of the product or service can be measured by multicriterion methods described in numerous published works (Abdelrahman et al. 2008; Alsugair 1999; Holt 1998; Lai et al. 2004; Zhang 2004). The price equilibrium reached in the market is a state in which economic forces are balanced and the equilibrium values of economic variables remain constant (Scherer 1980). The economic forces are related to several influential factors, such as external market conditions (e.g., pricing strategies and number of competitors, services offered) and contractors’ internal conditions (capabilities, experience, management skills, and other resources of contractors to provide a higher quality of work) (Ngai et al. 2002; Oo et al. 2008, 2010; Skitmore and Runeson 2006; Skitmore and Smyth 2007). Ultimately, contractors will submit a bid price based on the required quality of work they commit to a procurement entity. As a result, the heterogeneity of a BV tender is associated with the combination of bid price and the committed quality of contractors participating in the tender. That is, the slope of quality variation will be different for different contractors in the marketplace when the bid price changes. Therefore, the heterogeneity of a BV tender can be measured by the slope of the quality variation with respect to the
price variation. Such a measurement is similar to the definition of price elasticity of demand in economics (Case and Fair 1999), except that the demand is replaced with a broadly defined quality. In this paper, the price elasticity of quality is defined as “the measure of responsiveness in the quality for a product as a result of changes in price of the same product or service.” For convenience, the price elasticity of quality (PEQ) is called quality elasticity for short.

The foregoing PEQ definition of heterogeneity focuses on two major factors, cost and a broadly defined quality. Contractors’ internal factors (e.g., capabilities, experience, management skills, and other resources to provide higher-quality products or services) will affect the quality of work they offer at a specific price and thus are reflected in the PEQ definition. Other external factors, such as the number of competitors and the products or services on offer relevant to the contractors’ opportunistic bidding behaviors, are not included in the current definition.

### Existing Models for Pricing of Best Value Tenders

Although there is no explicit quantitative model in the literature for measuring the PEQ described in the last section, some previous works have shown similarities to the problem formulation of this research. The first category was found in the innovative contracting method, namely, the A + B method (Herbsman et al. 1995; Shen et al. 1999). A + B bidding is a method of rewarding a contractor for shortening the construction duration of the project as much as possible. By providing a cost for each working day, the contract combines the construction cost to perform the work (A) with the social cost of the impact to the public (B) to provide the lowest combined cost bid to the public. In the A + B method, the single quality criterion specified by the client is the construction duration (time), and the quality variation with respect to the price variation is related to the unit time value (UTV) that is measured by the daily road user’s cost (DRUC) (El-Rayes 2001; Herbsman et al. 1995; Herbsman and Glagola 1998; Shen et al. 1999). Analytic and statistical regression models have been developed to estimate the DRUC in the A + B method (El-Rayes 2001; Herbsman et al. 1995; Herbsman and Glagola 1998; Shen et al. 1999; Yu and Lo 2005).

Among the many A + B models, the optimal bid model (OBM) proposed by Shen et al. (1999) attracts our attention in particular. In OBM, Shen et al. formulated a quantitative model that combined both the traditional time/cost trade-off model with the UTV of A + B. The result is an equation for calculating the total combined bid (TCB) of the contractor, as shown in Eq. (1) (Shen et al. 1999):

\[
TCB_i = p_i + (UTV \times t_i)
\]

where TCB\(_i\) = total combined bid of i\(_{th}\) contractor; \(p_i\) = A component (construction cost) offered by i\(_{th}\) contractor; \(t_i\) = B component (construction duration) offered by i\(_{th}\) contractor; and UTV = DRUC given by client.

The contractors’ overall competitiveness were mapped with a TCB isomap, which plotted the TCB of every contractor with respect to the construction time (the single quality criterion) and resulted in an isoline (of equivalent competitiveness) for each contractor (Fig. 1). The OBM provides a very appealing formulation for measuring the PEQ described previously. The slope of the isoline in the TCB isomap of Fig. 1 is relevant to the UTV determined by the client. As a result, the UTV is closely related to the definition of PEQ.

Extending the unitary quality criterion (construction time) to a broader definition of quality of a BV tender, the graphic model of OBM by Shen et al. becomes the geometric graph analysis (GGA) model proposed by Wang and Yu (2007). The GGA model tackles the two most important factors (i.e., price and quality) for the pricing of a BV tendering project. In the GGA model, the relationship between price and quality is modeled with a two-dimensional diagram, where the x-axis represents the broadly defined quality and the y-axis represents the price offered by the contractor (Fig. 2).

The two most interesting curves in a GGA graph are LQ (lowest-quality curve) and HQ (highest-quality curve). Every point \((x, y)\) in a GGA graph represents a tender with a set of the quality \((Q)\) and price \((P)\) offered by a specific contractor. In the GGA model, Q can be defined by multicriterion methods such as those proposed by Abdelrahman et al. (2008), Zhang (2004), Alsugair (1999), Lai et al. (2004), Holt (1998), and many others. A convenient simple weighting method for measuring the broadly defined (multicriterion) quality was proposed by Gale and Swire (2006) using a set of predefined performance indicators (PIs) as described by Eq. (2):

\[
q_i = \sum_{j=1}^{n} S_j \times W_i
\]

where \(q_i\) = broadly defined quality of i\(_{th}\) tender; \(S_j\) = score of i\(_{th}\) PI; \(W_i\) = weight of i\(_{th}\) PI; and \(n\) = number of PIs taken into consideration.

Various methods can be applied to determine the broadly defined quality in BV tendering, such as (1) overall evaluated score method (OESM)—the tender with the highest overall score, calculated using a simple weighting method, is awarded; (2) price per score point method (PPSP)—the tender with the lowest price/score...
ratio (or price/quality ratio) is awarded; (3) ranking method (RM)—a derivation of OESM, which replaces the overall scores with the orders for the tenders; and (4) others—any other approaches as approved by the responsible entity (Public Construction Commission 2008). Of these, OESM is the most popular method for BV tendering in Taiwan. As a result, only OESM that evaluates bids with numerical scores according to a set of predefined criteria is considered in this paper.

The final missing piece for solving the PEQ measurement problem is a quantitative formulation of quality variation to price variation (the slope). This can be easily found from existing models of the price elasticity of demand in economics (Case and Fair 1999). However, while replacing the demands in those models with the broadly defined quality, the function of the curves in a GGA graph become a utility function instead of the demand and supply curves in neoclassical microeconomics.

**Model Formulation**

**Graphic Model**

Adopting the existing models reviewed in the previous section, a quantitative model for measuring PEQ is developed. The GGA model is adopted as the graphical analysis tool. From a contractor’s perspective, every point in a GGA graph represents a possible tender (with a set of price and quality level) offered by a contractor. The increase in price offered by the client will encourage the contractor to provide a better-quality product or service. According to Dolan and Simon (1996), the bid price increases as the quality of the product or service improves. In other words, the product or service with better quality will be quoted at a higher price. However, the marginal cost for the improved quality exceeds a certain level of quality due to the limited technological capabilities of the contractors. This results in a concave curve (similar to HQ) in Fig. 2, where the slope of the concave curve relates to the capability heterogeneity of the contractors addressed by Gonzalez-Diaz et al. (2000) and Oo et al. (2008, 2010). Connecting all the tenders of the highest quality products or services for different price levels, it yields the lower-bound envelope curve HQ. Ideally, there will be a most-capable contractor who possesses the best management skills, resources, technologies, and experience to perform a similar type of project, and thus that contractor’s tenders will constitute the HQ curve.

The other way to view the graphic model is from the client’s perspective. The perceived value of the procurement entity (i.e., the price that the procurement entity is willing to pay for a specific quality level of the product or service) rises as the product or service quality improves (Dolan and Simon 1996). However, the marginal utility of the performance of the procurement entity declines as the price increases due to the limited budget and the nature of diminishing marginal returns (Samuelson and Nordhaus 2001). This results in a convex curve (similar to LQ) in Fig. 2. Connecting all the upper-bound envelope curve LQ.

If LQ falls below HQ, no successful tendering would occur. This is because the price the procurement entity would like to pay for the required level of quality of the product or service is beyond the capability of the contractors in the market. It was recognized by many previous researchers that contractors may bid for a project under their budgets in order to mitigate the high overhead costs during the bad years (Oo et al. 2008, 2010; Runeson and Rafferty 1998; Skitmore 1991; Skitmore et al. 2006; Skitmore and Smyth 2007). However, a representative HQ can still be constructed based on prevailing market conditions. The other notable point is the difference between LQ and HQ curves (for a specific quality level), which indicates the maximum potential profit attainable for the contractors at that quality level.

The HQ and LQ curves described previously provide an analytical tool for pricing BV tenders. The mathematical formulation of HQ and LQ is described in the following section.

**Mathematical Model**

The HQ and LQ curves in Fig. 2 are essentially utility functions in economics. There are two widely adopted utility functions (Clemen 1996): a cubic equation and a quadratic equation. Since a cubic equation may encounter problems with the multiple reflection points of a curve, this paper adopts quadratic equations to simplify the mathematical model. A general quadratic equation is Eq. (3), and HQ and LQ are formulated in Eqs. (4) and (5), respectively:

\[
y = f(x) = ax^2 + bx + c
\]

(3)

\[
y_1 = f(x)_{HQ} = a_1x^2 + b_1x + c_1
\]

(4)

\[
y_2 = f(x)_{LQ} = a_2x^2 + b_2x + c_2
\]

(5)

The value of \( y \) represents the price (\( p \)) and the value of \( x \) reveals the quality level (\( q \)) associated with \( p \), respectively, in Eqs. (3)–(5); the subscripts HQ and LQ indicate the envelope curves associated with those equations.

Taking the first derivative of Eq. (3), it gives the slope of the tangent line to the curve:

\[
f'(x) = m = 2ax + b
\]

(6)

where Eq. (6) depicts the tangent line to the curve at (\( x, y \)), and \( m = \) slope of the tangent line at point (\( Q, P \)) in the GGA graph.

As stated previously, the measurement of PEQ is similar to that of price elasticity of demand (PED) in economics. According to Case and Fair (1999), PED can be measured as the ratio of percentage of changes between the demanded quantity of a good and its price. Similarly, PEQ can be defined as the ratio of percentage of changes in the committed quality level as a result of variation in price. Based on the preceding definition, PEQ can be calculated using the following equation:

\[
PEQ = \frac{\Delta Q/Q}{\Delta P/P} = \frac{\Delta Q}{\Delta P} \times \frac{P}{Q} = \frac{1}{m} \times \frac{P}{Q}
\]

(7)

where PEQ = measurement of price elasticity of quality; \( Q = \) quality level of product or service; \( \Delta Q/Q = \) percentage of variation in quality level; \( P = \) price; \( \Delta P/P = \) percentage of variation in price; and \( m = \) slope of tangent line at point (\( Q, P \)) in the GGA graph defined in Eq. (6).

**Best Value Pricing Strategy Planning**

In BV tendering, the procurement entity’s goal is to achieve the overall optimum objectives for the project. As a result, the lowest price is not the sole criterion. In other words, different quality levels for a product or service quote different acceptable price levels to the procurement entity. In Fig. 2, the points on the LQ curve represent the collection of the highest-price tenders that the procurement entity is willing to accept for the specified quality levels. In a fair competitive market, the LQ should be the same for all competitors. Thus, tenders on the LQ curve are the strategic target that all
contractors would like to attain in order to achieve their maximum revenue (i.e., to leave the least money on the table).

On the other hand, the HQ curve represents the collection of all the lowest-necessary-price tenders (with respect to different quality levels) for a contractor in the market to provide the quality specified by the procurement entity. Since the contractors are heterogeneous in their management skills, resources, and experiences (Gonzalez-Diaz et al. 2000; Oo et al. 2008, 2010), the HQ curves for individual contractors should be different. Theoretically, there exists a contractor who is the most efficient at providing the product or service; thus, that contractor’s tenders constitute the HQ. The HQ of Fig. 2 should be different from the price-time curve suggested by Shen et al. (1999) in the OBM since the x-axis of Fig. 2 represents the broadly defined quality rather than time. The curves will be constructed empirically using the data collected from the real-world market in the demonstrated examples.

To plan the bidding strategy for the contractor, a total BV bid (TBV) similar to the TCB proposed by Shen et al. (1999) is derived using the following equation:

\[ TBV = p + (m \times q) \]  

(8)

where TBV = total BV bid for a tender; \( p \) = price of tender; \( q \) = quality level of tender; and \( m \) is defined in Eq. (6).

There are two perspectives to evaluate the TBV defined in Eq. (8). From the viewpoint of the client, an acceptable TBV for the minimum quality requirements (specified in the contracting documents) should be located on the LQ curve in Fig. 2. From the viewpoint of the client, an acceptable TBV for the minimum quality requirements (specified in the contracting documents) should be located on the LQ curve in Fig. 2. All tenders on LQ quote the same utility for the procurement entity. It constitutes a selection curve, that is, the procurement entity’s utility-characteristic curve (UCC). To increase the utility of the procurement entity (and thus the probability of winning the bid), the contractor must either reduce the price for the same quality or increase the quality at the same price; as a result, the UCC will move toward the lower right side of the GGA graph.

From the contractor’s perspective, an achievable tender with the best capability of the contractor will be located on his or her own HQ curve, similar to the HQ curve in Fig. 2. All tenders on HQ indicate the ultimate capability of the same contractor to perform the contract. Under such conditions, the contractor will earn no profit. This constitutes the contractor’s capability-characteristic curve (CCC). To increase the profit, the contractor must either increase the price with the same quality or decrease the quality (and thus the cost) at the same price; as a result, the UCC will move toward the upper left side of the GGA graph.

According to the preceding discussion, the most competitive strategy for a contractor to win a BV tender would be the one that maximizes the overall utility of the procurement entity, i.e., moving UCC down to the right. However, the most profitable strategy for the contractor to achieve the maximum expected profit (MEP) should be the one that maximizes the gap between the LQ and HQ curves, as described at the end of the subsection headed “Graphic Model.” The optimum bidding strategy for a BV tender should take these two factors into consideration simultaneously.

**Most Competitive Strategy**

Consider the GGA graph in Fig. 3. The procurement entity’s UCC with respect to the quality of a product or service will look like the curved shape of LQ, as discussed in the subsection headed “Graphic Model.” A specific UCC, denoted UCC0, can be viewed as the minimum indifference curve (or indifference curve) for the UCC of the procurement entity because it satisfies the minimum requirement specified in the specification by the procurement entity. Other similar isocurves of different utility levels can be constructed for the procurement entity and denoted by UCC1 in Fig. 3.

Assume that there exists a most efficient contractor with the capability-characteristic curve CCC∗ in Fig. 3; the most competitive bidding strategy for the contractor would be \( T^* \), as indicated in Fig. 3. Other, less efficient, contractors should submit a TBV higher than the one located on \((q^*, p^*)\). The question is: what would the coordinates \((q^*, p^*)\) of the most competitive tender \( T^* \) be?

Because the exact location of the procurement entity’s UCC∗ is unknown, it is hard to develop an exact analytic solution. However, if we assume that the shape of the UCCs for different utility levels remains the same, then the \( T^* \) should be located at that point on HQ where the tangent line is the same for both CCC∗ and UCC∗. Such an assumption provides a feasible solution for finding \( T^* \). Substituting Eqs. (4) and (5) into Eq. (6) yields

\[ f'_LQ(x) = 2a_2x + b_2 \]

(10)

Since the tangent lines are the same at \( T^* \), the \( x \)-coordinate of the tangent point \( T^* \) is located at \( a_1x + b_1 = a_2x + b_2 \); this gives

\[ x = \frac{b_2 - b_1}{2(a_1 - a_2)} \]

Substitute this \( x \)-coordinate value into Eq. (4); this gives the coordinate of

\[ y = a_1 \left[ \frac{b_2 - b_1}{2(a_1 - a_2)} \right]^2 + b_1 \left[ \frac{b_2 - b_1}{2(a_1 - a_2)} \right] + c_1 \]

As a result, the coordinate of the most competitive tender \( T^* \) is located at

\[ \left( x = \frac{b_2 - b_1}{2(a_1 - a_2)}, y = a_1 \left[ \frac{b_2 - b_1}{2(a_1 - a_2)} \right]^2 + b_1 \left[ \frac{b_2 - b_1}{2(a_1 - a_2)} \right] + c_1 \right) \]

(11)

**Most Profitable Strategy**

The tender of \( T^* \) described in the last subsection suggests the most competitive strategy for a contractor to win a bid. However, as was pointed out earlier in this section, any tender on CCC∗ yields no profit to the contractor. To achieve the MEP, a second strategy is developed for the contractor. Consider the GGA graph of Fig. 3. The MEP of the contractor can be achieved while the gap between
UCC₀ and CCC⁺ is maximized, i.e., the T¹ tender with the coordinate (q₁, p₁). At T³, the quality requirement by the procurement entity is q₁ and the highest acceptable tender price for the client is p₁. However, the contractor is able to achieve that required quality (q₁) at a cost of p₂. This provides a gap in price difference (p₁−p₂) that is attainable for the contractor. To find out the coordinates of T³, the quality level (q₁) that maximizes the gap is sought. Subtract the price of UCC, Eq. (5), by the price CCC, Eq. (4); this gives the gap in price difference between the two curves in

\[
y_{\text{Gap}} = f(x)_{\text{UCC}} - f(x)_{\text{CCC}} = (a_2 - a_1)x^2 + (b_2 - b_1)x + (c_2 - c_1) \tag{12}
\]

where the subscripts UCC and CCC define the curve types; other symbols and subscripts are defined as in Eqs. (4) and (5).

Eq. (12) remains a parabola function. The maximum gap in the price difference characterized in Eq. (12) is located at

\[
(x = \frac{b_2 - b_1}{2(a_1 - a_2)}, y = a_2 \left[ \frac{b_2 - b_1}{2(a_1 - a_2)} \right]^2 + b_2 \left[ \frac{b_2 - b_1}{2(a_1 - a_2)} \right] + c_2) \tag{13}
\]

where symbols and subscripts are defined in Eq. (12).

Since the tender with coordinates of Eq. (13) in the GGA graph quotes the maximum expected profit, T¹ is considered the most profitable tender for the contractor.

**Summary of Best Value Bidding Strategy**

By combining both strategies derived in this section, it is found that the x-coordinates of Eqs. (11) and (13) are identical. This suggests that the optimum quality level for contractor is located at

\[
x = \frac{b_2 - b_1}{2(a_1 - a_2)}
\]

both for winning a bid and achieving the MEP. As a result, the optimum bidding zone for a BV tender is between T¹ and T*, i.e., commit a quality level at

\[
x = \frac{b_2 - b_1}{2(a_1 - a_2)}
\]

while submitting a bid price between \([p^*, p_1]\). The contractor should never bid below \(p^*\) and should never overpromise higher than \(q^*\). The bidding strategy suggested by the proposed model provides not only a bidding zone for pricing a tender but also an associated recommended quality level. Should the perceived quality level be obviously unattainable at the price in the bidding zone, the contractor should decide not to bid to avoid loss of profit. This can also be considered more profitable strategy compared with the bid-and-lose strategy. As a result, it is expected that the bidding strategy of the contractor will be more adequately supported with the suggested bidding zone.

**Demonstration Examples**

Two tendering projects are selected as working examples for the proposed BV pricing method. The first example is adopted from the work of Gale and Swire (2006) for a BV product supplying project. The second example is selected from a historical design and build (D/B) construction project issued by the Department of Defense (DOD) of Taiwan. Neither of the demonstration projects was bid on using the proposed pricing model. However, the historical procurement data in both examples are used to provide the required information for adopting the proposed model in order to demonstrate the feasibility of the proposed method.

**Example 1: Product Supplying Project**

The product supplying project is selected from a published paper by Gale and Swire (2006). The objective of the original paper was to acquire the target product at the best value for the client. In this demonstration example, the product procurement data provided in the paper will be used to determine the optimum pricing strategy for the contractors who intend to bid. Such procurement data can also be easily obtained by the contractor by surveying the prevailing market information according to the client’s quality criteria. The procurement target in the example was air cleaners. Four quality criteria of the product were specified as the client’s PIs associated with Eq. (2). These included (1) dust (capability to clean dust); (2) smoke (capability to clean smoke); (3) noise (noise generated during operation); and (4) ease of use (operation steps and maintenance requirements, for example). The resulting weighting factors of the four PIs are shown in the second column of Table 1.

The contractor’s pricing strategy for the project is to determine the optimum pricing strategy that takes into account both competitiveness and profitability. To achieve this objective, the contractor organizes an internal assessment taskforce to conduct market surveys. A total of 16 brands of air cleaners provided by 6 different potential competitors are identified by the assessment taskforce. The products are then evaluated by the assessment taskforce to determine the quality of the six vendors measured by the four PIs defined by the client in the procurement document. The evaluation results, scored from 1 to 10, are shown in Columns 3–8 of Table 1.

Based on the data shown in Table 1, a GGA graph is constructed (Fig. 4). A statistical regression is conducted to determine the best-fitted upper-bound (LQ) and lower-bound (HQ) envelopes using quadratic Eqs. (4) and (5). The resulting quadratic equations are shown in Eqs. (14) and (15). The coefficient of determination, \(R^2\), is 0.9977 for Eq. (14) and 0.9101 for Eq. (15); both show as highly fitted:

\[
f(x)_{HQ} = 26.65x^2 - 203.06x + 745.16 \tag{14}
\]

\[
f(x)_{LQ} = -7.3833x^2 + 174.3x - 165.13 \tag{15}
\]

Using the functions of HQ and LQ in Eqs. (14) and (15), the most competitive tender \(T^*\) is located at \((5.54, 438.5)\) and the most profitable tender is located at \((5.54, 547.3)\). The suggested bidding strategy is to offer a tender with a committed overall quality of \(x = 5.54\). The suggested bidding strategy for the project is to determine the optimum pricing strategy for the client.

**Table 1. Tender Evaluation Results of Example 1 [data from Gale and Swire (2006)]**

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Weighting</th>
<th>F</th>
<th>W</th>
<th>B</th>
<th>HW</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust</td>
<td>40%</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Smoke</td>
<td>30%</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Noise</td>
<td>20%</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Ease of use</td>
<td>10%</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Quality score ((q))</td>
<td>100%</td>
<td>7.5</td>
<td>7.1</td>
<td>6.0</td>
<td>5.5</td>
<td>4.1</td>
</tr>
<tr>
<td>Product price ((p))</td>
<td>USD</td>
<td>729</td>
<td>636</td>
<td>608</td>
<td>439</td>
<td>486</td>
</tr>
</tbody>
</table>

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to bid with a quality grade similar to that of Vendor H and at a price slighter lower than H in order to win the bid. The MEP of the project is US$108.8 (=547.3–438.5) per unit, or 19.9%, which is quite profitable. Whether or not the suggested bid price is profitable will depend on the capability of the vendor.

Example II: D/B Construction Project

The second demonstration example is selected from a historical construction project for a major renovation of a military base conducted by the DOD of Taiwan. The tender consisted of two office buildings, two residential buildings, a maintenance plant, a fuel station, and a warehouse. The total site area was 35,935 ha. The project objectives entailed (1) improving the districting of the site area, including living, working, training, and recreation districts; (2) providing high-quality landscape, including smooth and convenient flow lines and humanistic landscapes with respect to local cultural elements; (3) establishing an integrated maintenance system, including underground utility pipelines and automatic alarm and monitoring systems. The budget for the project was US$10,558,000. The planned project duration was 13 months.

The project owner believed that a D/B contract would be a better solution for this example were collected from the historical files of the project provided by the procurement entity. The procurement data were adapted to fit the requirements of the proposed method for demonstration purposes.

In the procurement document, five PIs and their associated weightings are predefined for the BV tender, as shown in Table 2, including (1) design idea (30%)—the overall design concept of the architecture; (2) execution plan (25%)—the completeness and feasibility of the project execution plans; (3) performance capability (25%)—both the financial and management capabilities of the contractor; (4) cost rationality (5%)—the rationality of cost items compared with prevailing market prices; and (5) presentation and Q&A (15%)—the contractor team’s understanding of the key project issues and associated solutions.

Contractor No. 1 is considered here in this demonstration as the intentional contractor to bid for the tender. An assessment taskforce of domain experts from the contractor is organized. Then market surveys and reviews of previous encounters from the firm’s historical files are conducted by the contractor’s assessment taskforce to identify potential competitors. A total of 10 potential competitors are identified. The competitors’ (q, p) data for the target tender are evaluated by the members of the contractor’s assessment taskforce based on the contractor’s previous encounters with those competitors, according to the five PIs specified in Table 2. A quality evaluation of the competitors is conducted using a relative comparison method, i.e., Contractor No. 1 is considered to be the basis for comparison. Each evaluator (member of the contractor’s assessment taskforce) is asked to rate the scores of the five PIs for each of the other 10 potential competitors, and the PI scores are summed using Eq. (2) and the weightings of Table 2 to give the quality grade (q) of the competitor. In addition, the possible tender price for each potential competitor is estimated based on the record of previous encounters. Finally, the evaluation results of (q, p) for Contractor No. 1 and the other 10 potential competitors are summarized in Table 3.

Based on the quality and price information in Table 3, a GGA graph of Example II is plotted, as shown in Fig. 5. The ID numbers of the contractors are indicated above the located spots. By statistical regression, the best-fitted quadratic curves for LQ and HQ are shown as upper- and lower-bound envelopes in Fig. 5. The quadratic equations for LQ and HQ curves are obtained and shown by Eqs. (16) and (17), respectively:

\[
f(x)_{\text{LQ}} = -0.6167x^2 + 103.18x + 6252.7 \quad (17)
\]

\[
f(x)_{\text{HQ}} = 0.5556x^2 - 85.497x + 13811 \quad (16)
\]

The resulting coefficient of determination (R^2) is 0.8655 for Eq. (16) and 0.9677 for Eq. (17), indicating highly fitted curves.

Using the functions of HQ and LQ in Eqs. (16) and (17), the most competitive tendering point T* should be located at (80.5, 10,529). The most profitable tender is located at (80.5, 10,562).

The suggested bidding strategy is to offer a tender with a committed quality grade equivalent to 80.5, which is very close to the current quality level of Contractor No. 1 (intentional contractor) for the target tender. On the other hand, the bidding zone for the tender

---

**Table 2. Quality Measurement Criteria and Their Weightings for Example II**

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Design idea</th>
<th>Execution plan</th>
<th>Performance capability</th>
<th>Cost rationality</th>
<th>Presentation and Q&amp;A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighting (%)</td>
<td>30</td>
<td>25</td>
<td>25</td>
<td>5</td>
<td>15</td>
</tr>
</tbody>
</table>

Note: Q&A = question and answer.

**Table 3. Tender Assessment Results of Example II**

<table>
<thead>
<tr>
<th>Contractor Identifier</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality grade (q)</td>
<td>80.7</td>
<td>78.2</td>
<td>82.4</td>
<td>78.0</td>
<td>82.5</td>
<td>82.1</td>
<td>84.2</td>
<td>80.7</td>
<td>84.7</td>
<td>76.8</td>
<td>82.8</td>
</tr>
<tr>
<td>Price (p) (thousands of US$)</td>
<td>10,528</td>
<td>10,553</td>
<td>10,538</td>
<td>10,523</td>
<td>10,545</td>
<td>10,531</td>
<td>10,556</td>
<td>10,561</td>
<td>10,550</td>
<td>10,538</td>
<td>10,569</td>
</tr>
</tbody>
</table>
Combining both cost-based and market-based pricing models: As mentioned previously, Contractor No. 6, who is expected to offer (82.1, 10,531) as his/her bid, is a strong competitor to Contractor No. 1 and very likely to win the bid. As a result, the project would be unprofitable (MEP = 0.32%) to Contractor No. 1. It is not recommended that Contractor No. 1 bid for this project unless Contractor No. 6 does not bid for it. If Contractor No. 1 decides that it must win the target tender due to the organization’s strategic objective, a bid price slightly lower than 10.531 and a minimum committed quality level of 82.1, which is slightly higher than the current quality level of the intentional contractor, is recommended.

Discussions

The proposed PEQ method has been demonstrated with two application examples. Issues regarding the novelty, applicability, and underlying assumptions of the proposed method are discussed in this section.

Novelty of Proposed Method

- Measuring the heterogeneity of best value tenders: Earlier tender pricing methods focused on LB; a rare pricing method was found to handle BV tenders. One key reason for the lack of a BV pricing method is the difficulty of measuring the heterogeneity of the tenders. The heterogeneity of BV tenders is mainly due to differences in capabilities, management skills, and experience among bidders in fulfilling the same types of projects (Gonzalez-Diaz et al. 2000; Oo et al. 2010). This paper proposed a PEQ model to measure the heterogeneity of a tender in terms of its elasticity of quality with respect to the variation in bid price. With a constructed GGA, the contractor is able to determine a bidding zone to price a target tender based on a recommended quality level. Such a BV pricing supports the contractor’s decision more adequately.

- Combining both cost-based and market-based pricing models: As stated in the section headed “Tender Pricing Models Revisited,” there are two independent tender pricing methods in the literature: the cost-based model (Benjamin 1972; Carr 1982; Crowley 2000; Dixie 1974; Engelbrecht-Wiggans 1980; Grifffis 1992; Ioannou 1988; Skitmore 2002, 2004; Skitmore et al. 2007) and the market-based model (Hiliebrandt 1974; Ngai et al. 2002; Runeson and Raftery 1998). The former prices a tender by the estimated cost of fulfilling a contract and the associated a priori probability function of winning the bid given a specific profit margin; the latter determines the price equilibrium reached in the market based on neoclassical microeconomic theory. The proposed method combines both cost-based and market-based pricing models, i.e., the different quality of work done by a contractor of the PEQ model reflects the internal capability of the contractor, which is reflected in the cost of performing the contract (cost-based model); the suggested bid price should consider the price equilibrium reached in the market, which follows the pricing rule of neoclassical microeconomics (market-based model). Such a combination integrates perspectives of both models.

- Integration of both competitive and profitable strategies in one model: One important finding of the present research is that both the most competitive and profitable strategies suggest the same quality level. This means that no matter which strategy a company adopts, there exists a recommended optimal quality level for a tender. The only question left is how much to price the tender. The proposed method suggests a bidding zone for the contractor instead of an exact bidding price because determination of the final bid price may be affected by many other factors, including market conditions, the contractor’s current work load, and the firm’s future development strategy. The contactor can make his or her final decision by taking into account both the internal and external contexts. In the two demonstration examples, thoughts for determining a final bid price are discussed in terms of an organization’s strategic objectives.

Applicability of Proposed Method

- Predictability of competitors’ bidding prices: The price information of products provided by competitors is available in the marketplace. However, predicting the bidding prices of potential competitors for a complicated project (such as the D/B project in Example II) may not be easy. Earlier researchers found that relatively accurate estimates could be attained by an ex post analysis of the competitors’ bidding history from previous encounters. This was also the essential assumption for the cost-based tender pricing models (Friedman 1956; Gates 1967; Benjamin 1972; Dixie 1974; Carr 1982; Skitmore 2002; Skitmore et al. 2007). In Example II, an assessment taskforce was organized by the intentional bidder to survey the price information. Such an approach is common in the construction industry.

- Measurability of quality for a best value tender: The other requirement for adopting the proposed method is to measure the quality of a BV tender in terms of the performance indicators defined by the client. Such a measurement can be easily obtained via market surveys for a product procurement tender (e.g., Example I); however, it would be relatively difficult for a complicated project (e.g., Example II). Numerous researchers have devoted themselves to developing multicriterion decision-making methods for evaluating the quality of a BV tender (Abdelrahman et al. 2008; AlSugair 1999; Holt 1998; Lai et al. 2004; Zhang 2004). Given the existence of such multicriterion performance measurement models, measuring the quality of complicated BV tenders becomes feasible. In Example II, an assessment taskforce is organized by the intentional bidder to assess the quality levels of the potential competitors with respect to the target project on the basis of experience in previous encounters. In that case, the quality level of the intentional contractor is considered as the basis. Then relative comparisons between the intentional bidder and his or her competitors are conducted. The results are relative quality scores ranging from [10,529, 10,562] in thousands of USD. It is found that the suggested bidding zone is relatively narrow (only approximately 0.32% of the tender price) in this case. Moreover, Contractor No. 6, who is expected to offer (82.1, 10,531) as his/her bid, is a strong competitor to Contractor No. 1 and very like to win the bid. As a result, the project would be unprofitable (MEP = 0.32%) to Contractor No. 1. It is not recommended that Contractor No. 1 bid for this project unless Contractor No. 6 does not bid for it. If Contractor No. 1 decides that it must win the target tender due to the organization’s strategic objective, a bid price slightly lower than 10.531 and a minimum committed quality level of 82.1, which is slightly higher than the current quality level of the intentional contractor, is recommended.

Fig. 5. GGA graph of Example II

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1 to 100. Such an approach is a common practice for contractors who are bidding on a major project. Example II shows that the relative quality levels of the competitors are measurable if moderate effort is expended on performing the measurements.

Although an analytical method for determining the quality level of a submitted bid is difficult to establish, the recommended quality level can be inferred using a benchmarking method. That is, the quality level of the most relevant competitor provides a useful reference for the intentional bidder to commit (to the client) in performing the target work. This makes the proposed model feasible in real-world application to complicated projects such as that of Example II.

**Appropriateness of Assumptions for Proposed Method**

There are several underlying assumptions made for the proposed method. Their appropriateness are reviewed and discussed in what follows to validate the proposed method.

- Perfect competitive market assumption: A fair and perfectly competitive market is the underlying assumption for all neo-classical microeconomics models. In reality, there is no perfect market for the construction industry. After joining the World Trade Organization (WTO), many construction markets (including in the United States and Taiwan) have become increasingly closer to the presumed perfect market. In the proposed method, this assumption requires that every bidder be fairly treated, and no single player, either buyer or seller, in the market can individually affect the market price. The assumption presumably holds from the preceding viewpoint.

- Assumption of quadratic functions for HQ and LQ curves: Although a quadratic equation is not perfect, it seemingly approximates HQ and LQ curves well for the two demonstration examples in terms of the regression results. The reason why a quadratic function was adopted is that the HQ and LQ curves are essentially utility functions, and quadratic functions are commonly used in economics to model utility functions. In fact, quadratic equations can be replaced by any other type of curve as long as the derivatives of the curve can be calculated.

- Assumption of similar shape for client's utility-characteristic curves: The shape of the procurement entity’s utility-characteristic curves is assumed to be the same while deriving the most competitive strategy. Such an assumption holds as long as the procurement entity remains the same while assessing the different quality (utility) levels and the procurement entity is rational during the assessment process. Because the procurement entity remains the same for the same tender and is assumed to be rational, such an assumption should hold.

**Conclusions and Recommendations**

Best value (BV) is being increasingly adopted by public and private procurement entities in order to obtain higher-quality products and services. However, the pricing strategy of BV tenders has rarely been researched due to the difficulty of measuring the variation in quality with respect to price. In this paper, a price elasticity of quality (PEQ) model is proposed to measure the aforementioned variations. The proposed method constructs a quality-price two-dimensional graphical analysis, namely, geometric graph analysis (GGA). The most prevalent tendering data acquired from contractors encountered in the past are plotted in the graphic model. Two characteristic curves, the procurement entity’s utility-characteristic curve (UCC) and the contractor’s capability-characteristic curve (CCC), are drawn using statistical regression with the acquired tendering data. The contractor’s most competitive tender is positioned at the frontmost point on the procurement entity’s maximum utility curve while it is tangent to the contractor’s CCC. On the other hand, the contractor’s most profitable tender is positioned at the point where the gap between the UCC and CCC curves is maximized. It is found mathematically that the optimum quality levels for both strategies are identical. As a result, this suggests a BV bidding zone that is most beneficial to the contractor. It is concluded that the proposed BV pricing method provides contractors with an analytic tool to support their decisions in BV tendering more adequately.

Unlike the traditional lowest bid (LB) method and the innovative A + B contracting method, the BV pricing method is highly influenced by the perceived value of the procurement entity with respect to the committed quality offered by the contractor. In turn, the procurement entity’s perceived value is usually reflected by a set of evaluation criteria determined by the evaluation committee of the client. Numerous researchers have devoted themselves to developing multicriterion decision-making methods for bid evaluation. Very rarely did earlier research adopt such methods for assessing BV tenders from the contractor’s side. The proposed method adopts the existing BV evaluation models, combining them with the contractor’s internal assessment taskforce and a relative comparison method to form a feasible approach to pricing BV tenders. Moreover, a benchmarking method is suggested for the bidder to obtain a useful reference of the recommended quality level while applying the proposed model in practical BV tendering.

As an early attempt in BV pricing, several assumptions were made in order to achieve a determinate solution for a specific BV tender. These assumptions include the following: (1) the quality of a tender is measurable with a multicriterion method; (2) quadratic functions are suitable for HQ and LQ curves; and (3) the procurement entity’s utility-characteristic curves are similar. The issues regarding the assumptions, novelty, and applicability of the proposed method were discussed and addressed. All of these issues provide promising directions of future exploration for interested researchers.

**References**


