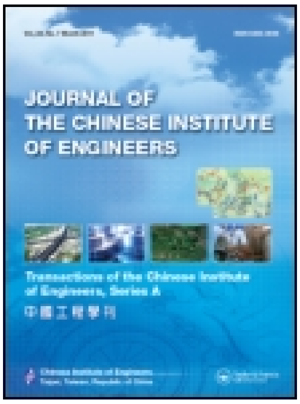

Journal of the Chinese Institute of Engineers
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tcie20

Evaluating bid item prices to support contractor selection - a case study

Chun-Chang Lin [a] , Wei-Chih Wang [b] & Jyh-Bin Yang [c]

[a] Department of Civil Engineering , National Chiao Tung University , Hsinchu, Taiwan 300, R.O.C.

[b] Department of Civil Engineering , National Chiao Tung University , Hsinchu, Taiwan 300, R.O.C. Phone: 886-3-5712121 ext. 54952 Fax: 886-3-5712121 ext. 54952 E-mail:

[c] Department of Construction Engineering , Chung-Hua University , Hsinchu, Taiwan, R.O.C.

Published online: 04 Mar 2011.

To cite this article: Chun-Chang Lin , Wei-Chih Wang & Jyh-Bin Yang (2007) Evaluating bid item prices to support contractor selection - a case study, Journal of the Chinese Institute of Engineers, 30:4, 765-771, DOI: 10.1080/02533839.2007.9671303

To link to this article: http://dx.doi.org/10.1080/02533839.2007.9671303

Short Paper

EVALUATING BID ITEM PRICES TO SUPPORT CONTRACTOR SELECTION – A CASE STUDY

Chun-Chang Lin, Wei-Chih Wang*, and Jyh-Bin Yang

ABSTRACT

Bid price is a highly-weighted appraisal criterion in a multi-criteria evaluation method to select contractors for construction projects. By evaluating both the magnitude and reasonableness of the bid price, this study presents an electronically-facilitated model for evaluating bid prices. The model defines a reasonable total price for a project and a reasonable cost for each cost category (or bid item) by considering the project prices estimated by the project owner and submitted by all qualified bidders. Scoring systems are then employed to score the prices submitted by bidders, and weighting methods are used to integrate the derived scores. The bidder with the highest integrated score receives the most favorable price appraisal. The merits of the proposed model are demonstrated by its successful application to a recent public construction project in Taiwan.

Key Words: project procurement, contractor selection, multi-criteria evaluation, bid item pricing.

I. INTRODUCTION

The lowest-bid method has been widely applied to award construction project contracts to bidders who submit the lowest bids. However, the lowest-bid method of construction contracting is widely regarded as a major cause of poor quality and excessive delay in Taiwan's construction industry. Thus, several other methods for awarding bids have been developed to improve the lowest-bid method (Ioannou and Leu, 1993; Holt, 1998). Among these improved methods, the multi-criteria evaluation method or the best value bid method has prevailed in many countries (Herbsman and Ellis, 1992; Alsugair, 1999; Pongpeng and Liston, 2003; Lai *et al*., 2004).

The best value bid (BVB) method is called the most advantageous bid method in Taiwan (PCC, 1998; PCC, 2000; Yang and Wang, 2003; Perng *et al*., 2006). The BVB method attempts to select a best-qualified contractor whose proposal is most favorable for the project owner by evaluating the bidder's proposed plans among other criteria, including bid price. Since the bid price is still a highly-weighted appraisal criterion, the evaluation of the bid price remains crucial to effective application of the BVB method. However, current practices and existing models relevant to bid-price evaluation focus on the total bid amount. Their price appraisal methods ignore how the total price is allocated to each cost category or bid item. Hence, this study proposes an electronically-facilitated bid-price appraisal model that supports the BVB approach for contractor selection.

II. MODELS FOR EVALUATING THE BID PRICE

Studies on evaluating competitive bids and multi-criteria bids both require the assessment of bid prices. For example, Crowley and Hancher (1995) proposed a quantitative method to assess apparently low bids according to the expected recurrence of scale

*Corresponding author. (Tel: 886-3-5712121 ext. 54952; Fax: 886-3-5716257; Email: weichih@mail.nctu.edu.tw)

C. C. Lin and W. C. Wang are with the Department of Civil Engineering, National Chiao Tung University, Hsinchu, Taiwan 300, R.O.C.

J. B. Yang is with the Department of Construction Engineering, Chung-Hua University, Hsinchu, Taiwan, R.O.C.

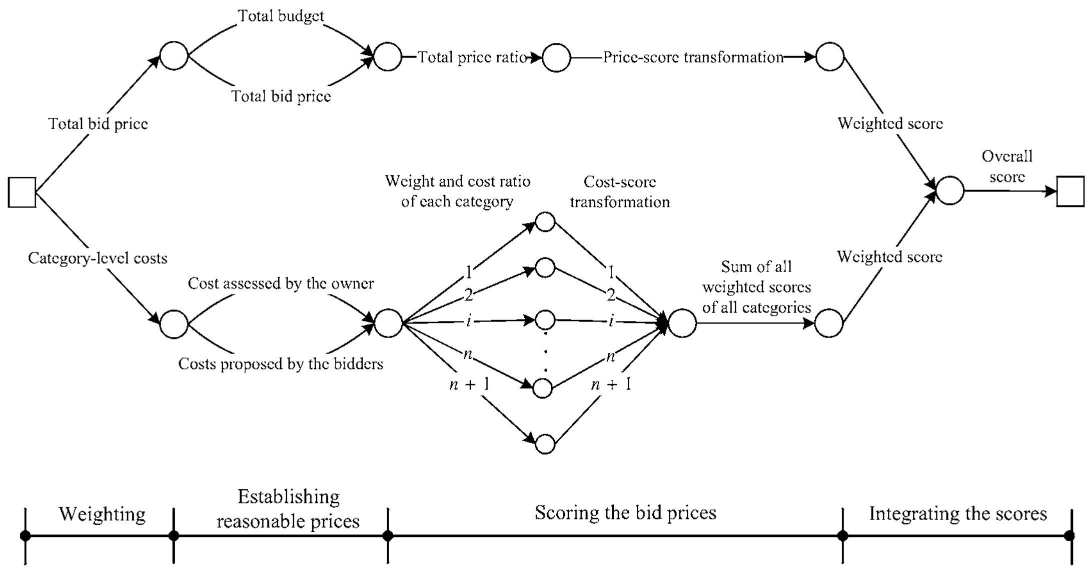

Fig. 1 Evaluation steps in the proposed model

deviations between the median and the low bid. Wang *et al* (2006) designed a model to identify which parts of a low bid were unreasonable, suspicious and reasonable. The decision was made according to whether the total unreasonable cost exceeded the total bid price by a predefined threshold ratio. In the model proposed by Alsugair (1999), an unbalanced bid (i.e., unreasonable allocation of bid item prices) was considered as an evaluation criterion. However, the method of evaluation is extremely subjective. Additionally, Yang and Wang (2003) established a transformation relationship between price ratio (total bid price divided by project budget) and score for supporting bid-price evaluations. Lai *et al* (2004) proposed a scoring method to assess total bid prices. Bid prices were scored according to how they deviated from a composite bid price that was the sum of the weighted average price of all bids and the weighted owner price. In sum, no price-evaluation models assess bid prices from both the total price level and bid-item price level.

III. THE PROPOSED BID-PRICE APPRAISAL MODEL

Project cost in Taiwan is commonly organized according to four estimate levels: total bid price level, cost category level, cost item level, and unit price level. In this study, the bid item refers to the cost category level. The proposed model is dependent on the use of an electronically-facilitated bidding procedure that requires bidders to submit bids electronically. This electronic file helps establish an integrated spreadsheet that combines the costs submitted by all parties, including the owner and the qualified bidders.

1. General Description of Evaluation Steps

The proposed model evaluates the bids in terms of the levels of total price and cost category. Evaluation proceeds in four steps (see Fig. 1): weighting the importance of the appraisal for the total price and category-level costs; establishing reasonable prices; scoring the submitted prices; and, integrating the overall scores. A general description for each step follows.

(i) Weighting

The model user (e.g., evaluation committee) determines two weighted values ($W1$ and $W2$) that represent the importance of the appraisal for the total price and category-level costs. Notably, the range of $W1$ (or $W2$) is 0 ~ 1. And the equation $W1 + W2 = 1$ is satisfied.

(ii) Establishing Reasonable Prices

The reasonable total price (or reasonable cost for each category) is calculated based on the total prices (or costs) prepared by the owner and all qualified bidders.

(iii) Scoring Prices

The model uses a price-score transformation system to assign a score, S_{tot-k}, for signifying the reasonableness of the total price submitted by bidder k. Additionally, the model assigns scores to represent the reasonableness of the costs for all cost categories in a similar cost-score transformation system. These category-level scores eventually will be weighted and then combined into a single score ($S_{cat\text{-}k}$) to represent the price-appraisal result for the category-level costs.

(iv) Integrating Scores

Finally, $W1$ and $W2$ are employed to integrate the two scores ($S_{tot\text{-}k}$ and $S_{cat\text{-}k}$) that identify the overall bid-price appraisal (denoted as FIN_k) for bidder k. The equation is as follows

$$FIN_k = W1 \times S_{tot\text{-}k} + W2 \times S_{cat\text{-}k}. \quad (1)$$

2. Evaluating Total Bid Price

(i) Establishing a Reasonable Total Price

The reasonable total price, $P_{tot\text{-}rea}$, is determined as follows

$$P_{tot\text{-}rea} = (\alpha \times B_o) + (\beta \times AVE), \quad (2)$$

where B_o is the total cost estimate of the project prepared by the owner. The value of AVE denotes the average of total bid prices submitted by all qualified bidders. Values α and β represent the weights of B_o and AVE, respectively. And the equation satisfied $\alpha + \beta = 1$.

(ii) Scoring Total Bid Price

As indicated earlier, the total bid price (denoted as $P_{tot\text{-}k}$) submitted by bidder k is transformed into a score ($S_{tot\text{-}k}$) based on a price-score transformation system. Fig. 2(a) presents a triangular shaped transformation system (i.e., $\wedge$). In Fig. 2(a), the X axis represents the value of total price ratio. The total price ratio for bidder k (denoted as Z_k) is the bidder's total price ($P_{tot\text{-}k}$) divided by the reasonable total price ($P_{tot\text{-}rea}$). That equation is represented as

$$Z_k = \frac{P_{tot-k}}{P_{tot-rea}}. \quad (3)$$

The Y axis of Fig. 2(a) indicates the score given a value of Z_k. The score for a particular Z_k is determined as follows. First, when $Z_k = 1.0 = Z2$, the highest score is assigned ($100 = S2$). Second, as Z_k becomes lower or higher than 1.0 ($Z2$), a low score is assigned. When Z_k equals the low limit ($Z1$) or the high limit ($Z3$), the lowest score ($S1$) is assigned. Third, if $Z_k < Z1$ or $Z_k > Z3$, the score is 0. Fourth, when $Z1 \le Z_k < 1.0$, the score ($S_{tot\text{-}k}$) for Z_k is computed as

$$S_{tot-k} = S1 + \frac{(S2 - S1)(Z_k - Z1)}{1 - Z1}. \quad (4)$$

Finally, when $1.0 < Z_k \le Z3$, the score ($S_{k\text{-}tot}$) for Z_k is computed as

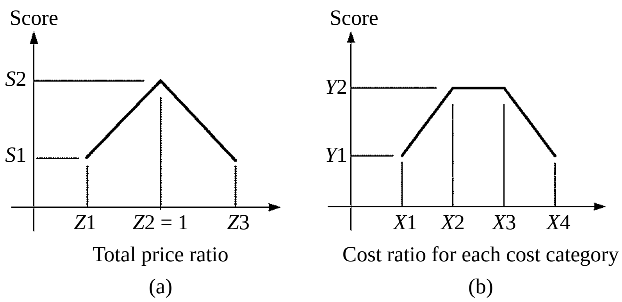

Fig. 2 (a) Triangular system to transform total price to score, (b) trapezoid system to transform cost to score for each cost category

$$S_{tot-k} = S1 + \frac{(S2 - S1)(Z3 - Z_k)}{Z3 - 1}. \quad (5)$$

In practical terms, the values determined for $Z1$ and $Z3$ relate to the acceptable lowest and highest bid ratios, respectively. It is proposed that $Z1$ should be less than 0.8, which is about the mean bid ratio of previous projects in Taiwan (Wang *et al.*, 2006). Assuming that $Z2$ (=1) is located an equal distance from $Z1$ and $Z3$ in Fig. 2(a), the value of $Z3$ can be decided as soon as the value of $Z1$ is set. The value of S1 is lowest when $Z_k = Z1$ or $Z3$.

3. Evaluating the Cost for Each Category

As indicated earlier, an integrated electronic file is generated prior to conducting the proposed model. The spreadsheet data includes the following: the category number; category description; owner's estimated cost; weight of each cost category; cost submitted by each bidder; average cost of all qualified bidders; and, reasonable cost for each category.

(i) Weight for Each Category

In the integrated spreadsheet, weight (w_i) for cost category i and owner's total-cost estimate or project budget (B_o) are calculated as

$$w_i = c_{o(i)}/B_o \quad (6)$$

$$B_o = c_{o(1)} + \cdots + c_{o(i)} + \cdots + c_{o(n)} + c_{o(n+1)}$$

$$= \sum_{i=1}^{n+1} c_{o(i)}, \quad (7)$$

in which $c_{o(i)}$ is the owner's estimated cost for category i ($i = 1, \cdots, n, n + 1$). Notably, categories 1 to n contain the major costs, such as direct costs, to be evaluated. The costs stored in the (n + 1)*th* category are the sum of other comparatively unimportant costs, such as indirect costs, to be evaluated. Furthermore, $w_1 + \cdots + w_i + \cdots + w_n + w_{n+1} = 1$.

(ii) Average Cost for Each Category

In the average cost for category i, $t_{(i)}$, is the mean value of all K qualified bidders. That is, $t_{(i)}$ is expressed as

$$t_{(i)} = \frac{c_{1(i)} + \cdots + c_{k(i)} \cdots + c_{k(i)}}{K}, \tag{8}$$

where $c_{k(i)}$ is the proposed cost for category i (i = 1, ⋯, n + 1) for bidder k (k = 1, ⋯, K).

(iii) Reasonable Cost for Each Category

The reasonable cost ($r_{(i)}$) for each category i is calculated as

$$r_{(i)} = p \times c_{o(i)} + q \times t_{(i)}, \tag{9}$$

where the values of p and q represent the weights of $c_{o(i)}$ (owner's cost) and $t_{(i)}$ (average cost among the bidders) for category i, respectively. And the equation p + q = 1 is made. Notably, the value of p (or q) in different cost categories can vary.

(iv) Cost-Score Transformation System for Each Category

Figure 2(b) displays the proposed cost-score transformation system with a trapezoid shape. The X axis is the cost ratio of each category; the Y axis represents the score with respect to a given cost ratio. The cost ratio of category i for bidder k, denoted as $Z_{k(i)}$, is computed based on the reasonable cost ($r_{(i)}$) and the proposed cost ($c_{k(i)}$) of category i for bidder k. That is, $Z_{k(i)}$ is expressed as

$$Z_{k(i)} = c_{k(i)}/r_{(i)}. \tag{10}$$

This score-price transformation system is defined by six parameters: $X1$ (low limit of cost ratio), $X2$, $X3$, $X4$ (high limit of cost ratio), $Y1$ (score with respect to the low limit), and $Y2$ (highest score = 100). The value of $X1$ is suggested to be below 0.8 (the mean bid ratio of previous projects in Taiwan), while the value of $X2$ can exceed 0.8. Assuming that 1.0 is located equal distances from $X1$ and $X4$ (or between $X2$ and $X3$) in Fig. 2(b), then the value of $X4$ ($X3$) can be determined as soon as $X1$ (or $X2$) is selected. The value of $Y1$ is lowest when $Z_{k(i)} = X1$ or $X4$.

(v) Integrating the Scores from All Categories

For each bidder k, the integrated score ($S_{cat\text{-}k}$ in Eq. (1)) from evaluating the category-level costs is derived by summing all weighted scores from each category. The summation is expressed as

$$\begin{aligned} S_{cat\text{-}k} &= (s_{k(1)} \times w_1) + \cdots + (s_{k(i)} \times w_i) + \cdots \\ &\quad + (s_{k(n)} \times w_n) + (s_{k(n+1)} \times w_{n+1}) \\ &= \sum_{i=1}^{n+1} S_{k(i)} \times w_i, \end{aligned} \tag{11}$$

where $s_{k(i)}$ is the transformed score with respect to category i for bidder k, and w_i is the weight with respect to category i (see Eq. (6)). Thus, the overall bid-price appraisal (FIN_k) shown in Eq. (1) is obtained for bidder k based on the obtained $S_{tot\text{-}k}$ and $S_{cat\text{-}k}$ values.

IV. CASE STUDY

The proposed model was applied to a recent National Nano Device Laboratories (NDL) construction project located in northern Taiwan. The total budget of the architectural subproject was US $12, 058,824 (during this work, US$1 equaled about NT$34). Three contractors, namely, A, B, and C, submitted bids. Each bidder met the prequalification criteria. The committee applied four evaluation criteria, including the bid price. During bid evaluation, each bidder presented his proposal followed by a question/ answer period. Then the model was applied for bid-price appraisal under the supervision of audit officers.

1. Evaluation in Bid Price Appraisal

(i) Appraisal Results of Total Price

The total bid prices for bidders A, B, and C were $12,052,765, $12,029,412, and $12,052,941, respectively. The AVE for the three bidders was $12, 045,039 and extremely close to the project budget (B_o = $12,058,824). An extremely close AVE was expected as all bidders knew that the BVB evaluation process was not looking for a lowest bid. The values of α and β were each set at 0.5. Then, the reasonable total price ($P_{tot\text{-}rea}$) was calculated to be $12,051,932 (Eq. (2)). Thus, the total-price ratios (i.e., Z_A, Z_B, Z_C) for bidders A, B, and C were 1, 0.998 and 1, respectively. Thus, according to the price-score transformation system shown in Fig. 2(a), in which $Z1$ = 0.6, $Z2$ = 1.0, $Z3$ = 1.4, $S1$ = 60 and $S2$ = 100, the scores of 100, 99.820, and 100 then were assigned to represent the total price appraisals for bidders A, B, and C, respectively.

(ii) Appraisal Results of Costs of Categories

The evaluation results for cost appraisal for each cost category are summarized in Table 1. In the case project, 32 cost categories were identified. The reasonable cost for each category, shown on the right of Table 1, was computed based on Eq. (9) (in which p = 0.5 and q = 0.5).

Table 1 Weight, average cost, and reasonable cost for each category

No.	Description of cost category	Owner's cost	Weight	Cost				Reasonable cost
				Bidder A	Bidder B	Bidder C	Average cost	
1	Office							
1.1	Temporary work	139,420	0.0116	126,490	136,945	152,552	138,663	139,041
1.2	Earth-moving	238,092	0.0197	264,270	205,030	140,340	203,213	220,653
1.3	Foundation	106,282	0.0088	127,294	128,760	142,883	132,979	119,631
1.4	Concreting	759,529	0.0630	725,563	760,867	763,987	750,139	754,834
1.5	Forming	592,444	0.0491	551,012	520,703	545,368	539,028	565,736
1.6	Rebar reinforcing	864,700	0.0717	967,184	886,393	966,182	939,919	902,310
1.7	Basement waterproofing	79,462	0.0066	77,039	76,726	64,634	72,800	76,131
1.8	Roof waterproof	70,099	0.0058	57,405	78,738	60,499	65,547	67,823
1.9	External wall	1,168,125	0.0969	1,101,840	1,090,620	1,233,131	1,141,864	1,154,994
1.10	Internal wall	542,428	0.0450	471,274	474,283	521,118	488,892	515,660
1.11	Ceiling	214,877	0.0178	209,501	193,785	192,314	198,533	206,705
1.12	Interiors	172,553	0.0143	138,690	157,973	144,592	147,085	159,819
1.13	Windows	458,172	0.0380	565,539	568,725	591,845	575,370	516,771
1.14	Landscape	154,431	0.0128	204,132	203,378	174,418	193,976	174,204
1.15	Shielding room	50,000	0.0041	61,765	50,000	58,824	56,863	53,431
1.16	Others	1,128,300	0.0936	1,016,960	1,227,869	1,068,686	1,104,505	1,116,402
2	Laboratory							
2.1	Temporary work	142,846	0.0118	146,526	162,769	182,207	163,834	153,340
2.2	Earth-moving	161,852	0.0134	179,864	133,108	91,361	134,778	148,315
2.3	Foundation	60,234	0.0050	89,595	64,196	92,222	82,005	71,119
2.4	Concreting	1,115,668	0.0925	1,050,361	1,101,275	1,121,817	1,091,151	1,103,410
2.5	Forming	610,457	0.0506	563,539	587,107	567,630	572,759	591,608
2.6	Reinforcing	1,077,971	0.0894	1,216,388	1,100,313	1,205,455	1,174,052	1,126,011
2.7	Steel	170,512	0.0141	174,344	167,754	152,769	164,956	167,734
2.8	Basement waterproof	70,965	0.0059	70,570	75,787	59,219	68,525	69,745
2.9	Roof waterproof	72,816	0.0060	55,432	81,586	67,636	68,218	70,517
2.10	External wall	244,539	0.0203	251,203	227,544	164,545	214,431	229,485
2.11	Internal wall	173,479	0.0144	147,207	163,559	167,321	159,362	166,421
2.12	Ceiling	42,549	0.0035	52,386	48,601	32,462	44,483	43,516
2.13	Interiors	80,064	0.0066	76,823	89,092	56,312	74,076	77,070
2.14	EPOXY	301,192	0.0250	340,784	297,899	339,112	325,931	313,562
2.15	Windows	216,058	0.0179	220,407	257,699	242,610	240,239	228,148
2.16	Others	778,708	0.0646	751,379	710,331	688,889	716,866	747,787
	Total	12,058,824	1.0000	12,052,765	12,029,412	12,052,941		

In the cost-score transformation system (Fig. 2(b)), the values of 0.5 and 0.9 were subjectively assigned to represent $X1$ and $X2$, respectively. Thus, $X3 = 1.1$ because $X2 = 0.9$, and $X4 = 1.5$ because $X1 = 0.5$. Additionally, the values of 50 and 100 were subjectively applied to represent the variables $Y1$ and $Y2$, respectively. The score and weighted score for the cost category for each bidder were then obtained. Table 2 presents these scoring results. The sums of these weighted scores for all cost categories for each bidder were 97.089, 98.055 and 95.854 for bidder A, B and C, respectively.

(iii) Results of Overall Bid Price Appraisal

Since the evaluation of total bid price was considered as important as the evaluation of category costs, then $W1 = W2 = 0.5$. The total scores for the bid price appraisal obtained by applying Eq. (1) were 98.544 (= 100.00 × 0.5+97.089 × 0.5), 98.938 (= 99.820 × 0.5+98.055 × 0.5), and 97.927 (= 100.00 × 0.5 + 95.854 × 0.5) for bidders A, B and C, respectively. Notably, although bidder B did not receive the highest score in total-price appraisal, he received the highest overall-bid-price appraisal because of his high score in the category-level appraisal. Bidder A received the second highest score, followed by bidder C.

2. Acceptance of the Model

Based on the bidders' proposals and presentations, as well as the results of bid price appraisals, each

Table 2 Cost ratio, score and weighted score of each category for each bidder

No.	Weight	Cost-score transformation						Weighted scoer of each category		
		Bidder A		Bidder B		BidderC		Bidder A	Bidder B	Bidder C
		Cost ratio	Score	Cost ratio	Score	Cost ratio	Score			
1.1	0.0116	0.910	95.56	0.985	100.00	1.097	94.76	1.108	1.160	1.099
1.2	0.0197	1.198	83.59	0.929	97.69	0.636	65.11	1.647	1.924	1.283
1.3	0.0088	1.064	98.44	1.076	97.08	1.194	83.96	0.866	0.854	0.739
1.4	0.0630	0.961	100.00	1.008	100.00	1.012	100.00	6.300	6.300	6.300
1.5	0.0491	0.974	100.00	0.920	96.71	0.964	100.00	4.910	4.748	4.910
1.6	0.0717	1.072	97.57	0.982	100.00	1.071	97.69	6.996	7.170	7.004
1.7	0.0066	1.012	100.00	1.008	100.00	0.849	88.78	0.660	0.660	0.586
1.8	0.0058	0.846	88.49	1.161	87.67	0.892	93.56	0.513	0.508	0.543
1.9	0.0969	0.954	100.00	0.944	99.36	1.068	98.04	9.690	9.628	9.500
1.10	0.0450	0.914	95.99	0.920	96.64	1.011	100.00	4.320	4.349	4.500
1.11	0.0178	1.014	100.00	0.937	98.61	0.930	97.82	1.780	1.755	1.741
1.12	0.0143	0.868	90.87	0.988	100.00	0.905	94.97	1.299	1.430	1.358
1.13	0.0380	1.094	95.07	1.101	94.38	1.145	89.41	3.613	3.586	3.398
1.14	0.0128	1.172	86.47	1.167	86.95	1.001	100.00	1.107	1.113	1.280
1.15	0.0041	1.156	88.23	0.936	98.42	1.101	94.34	0.362	0.404	0.387
1.16	0.0936	0.911	95.66	1.100	94.46	0.957	100.00	8.954	8.841	9.360
2.1	0.0118	0.956	100.00	1.061	98.72	1.188	84.64	1.180	1.165	0.999
2.2	0.0134	1.213	81.92	0.897	94.16	0.616	62.89	1.098	1.262	0.843
2.3	0.0050	1.260	76.69	0.903	94.74	1.297	72.59	0.383	0.474	0.363
2.4	0.0925	0.952	100.00	0.998	100.00	1.017	100.00	9.250	9.250	9.250
2.5	0.0506	0.953	100.00	0.992	100.00	0.959	100.00	5.060	5.060	5.060
2.6	0.0894	1.080	96.64	0.977	100.00	1.071	97.72	8.640	8.940	8.736
2.7	0.0141	1.039	100.00	1.000	100.00	0.911	95.64	1.410	1.410	1.349
2.8	0.0059	1.012	100.00	1.087	95.93	0.849	88.79	0.590	0.566	0.524
2.9	0.0060	0.786	81.79	1.157	88.11	0.959	100.00	0.491	0.529	0.600
2.10	0.0203	1.095	95.04	0.992	100.00	0.717	74.11	1.929	2.030	1.504
2.11	0.0144	0.885	92.73	0.983	100.00	1.005	100.00	1.335	1.440	1.440
2.12	0.0035	1.204	82.91	1.117	92.57	0.746	77.33	0.290	0.324	0.271
2.13	0.0066	0.997	100.00	1.156	88.22	0.731	75.63	0.660	0.582	0.499
2.14	0.0250	1.087	95.91	0.950	100.00	1.081	96.50	2.398	2.500	2.413
2.15	0.0179	0.966	100.00	1.130	91.16	1.063	98.51	1.790	1.632	1.763
2.16	0.0646	1.005	100.00	0.950	99.99	0.921	96.80	6.460	6.459	6.253
							Total:	97.089	98.055	95.854

committee member (comprising seven members, M1 ~ M7) then scored each of the four criteria for each bidder. Evaluation of the bid price reveals that the proposed model facilitated the bid-price appraisal for the case project. Two out of the seven members (i.e., M1 and M3) assigned the highest scores to bidder B, followed by bidder A and bidder C. Three members (M2, M4 and M5) also gave the highest score to bidder B, but assigned the same scores to bidders A and C. The remaining two members (M6 and M7) assigned the same scores to all three bidders because they were only concerned with the total bid prices that were close. Nevertheless, these two members appreciated the model's ability to improve current practices.

V. LESSONS LEARNED

A sensitivity analysis was performed to examine how the values for parameters $W1$, $W2$, $\alpha(p)$, and β(q) affect the results of bid-price appraisal. Two main observations were made. First, when $W1 = 1.0$ (i.e., $W2 = 0.0$), the rankings from bid-price appraisal would be bidders A > C > B. A decrease in the value of $W1$ (e.g., the value of $W1$ is less than 0.5), increases the difference in scores from the bid-price appraisals; in this case project, bidder B turned out to be the highest from bid-price appraisal. Namely, the values of $W1$ and $W2$ could affect project results. Second, when the value of $\alpha(p)$ decreased (i.e., from 0.8 to 0.2), the scores increased. Nevertheless, the rankings from bid-price appraisal for the bidders remained the same (i.e., bidders B > A > C). Thus, in this case study, the values of $\alpha(p)$ and β(q) did not significantly affect project results.

Additionally, the values of those parameters (including $W1$, $W2$, α, β, p, q, $Z1$, $Z3$, $S1$, $X1$, $X2$, $X3$, $X4$ and $Y1$) can somewhat affect the bid-price appraisal results. Hence, these parameters values must be determined before opening bids (but only open to committee members) to ensure fairness and openness during evaluation. Finally, in this model, two bid prices could receive the same scores if their price deviations from the reasonable bid price resemble each other. Thus, the model does not compensate for a lowest bidder who can offer the same quality of materials/equipment at lower prices or implement innovative construction technologies at low prices.

VI. CONCLUSIONS

This investigation proposed a new model to support the evaluation of a bid price using the BVB method. Rather than only focusing on the total bid price level, the proposed model also assesses the reasonability of the bid price allocated to each cost category. The proposed model has been successfully applied to four real-world projects, including the case project described herein, the mechanical/electrical/plumbing subproject of NDL, and two public construction projects in southern Taiwan. Additional future work may extend the model to evaluate the unit price of each cost item.

ACKNOWLEDGMENTS

The authors would like to thank the National Science Council of Taiwan (Contract No. NSC92-2211-E-009-039) and the Ministry of Education of Taiwan under the Aim for the Top University (MOU-ATU) program for financially supporting this research. Dr. Huang, S. C. is appreciated for his support in applying the proposed model to the NDL project.

REFERENCES

Alsugair, A. M., 1999, "Framework for Evaluating Bids of Construction Contractors," *Journal of Management in Engineering*, Vol. 15, No. 2, pp. 72-78.

Crowley, L. G., and Hancher, D. E., 1995, "Evaluation of Competitive Bids," *Journal of Construction Engineering and Management*, Vol. 121, No. 2, pp. 238-245.

Herbsman, Z. J., and Ellis, R. D., 1992, "Multiparameter Bidding System - Innovation in Contract Administration," *Journal of Construction Engineering and Management*, Vol. 118, No. 1, pp. 142-150.

Holt, G. D., 1998, "Which Contract Selection Methodology?" *International Journal of Project Management*, Vol. 16, No. 3, pp. 153-164.

Ioannou, P. G., and Leu, S. S., 1993, "Average-Bid Method-Competitive Bidding Strategy," *Journal of Construction Engineering and Management*, Vol. 119, No. 1, pp. 131-147.

Lai, K. K., Liu, A. L., and Wang, S. Y., 2004, "A Method Used for Evaluating Bids in the Chinese Construction Industry," *International Journal of Project Management*, Vol. 22, No. 3, pp. 193-201.

PCC, 1998, Government Procurement Law. Public Construction Commission, Executive Yuan, Taiwan. Available: http://www.pcc.gov.tw/; 2006/10/21

PCC, 2000, *Regulations for Evaluation of the Most Advantageous Tender (in Chinese)*, Public Construction Commission, Executive Yuan, Taiwan. (http://www.pcc.gov.tw/; 2006/10/21).

Perng, Y. H., Juan, Y. K., and Chien, S. F., 2006, "Exploring the Bidding Situation for Economically Most Advantageous Tender Projects Using a Bidding Game," *Journal of Construction Engineering and Management*, Vol. 132, No. 10, pp. 1037-1042.

Pongpeng, J., and Liston, J., 2003, "TenSem: A Multicriteria and Multidecision-Makers' Model in Tender Evaluation," *Construction Management and Economics*, Vol. 21, pp. 21-30.

Wang, W. C., 2004, "Electronic-Based Procedure for Managing Unbalanced Bids," *Journal of Construction Engineering and Management*, Vol. 130, No. 3, pp. 455-460.

Wang, W. C., Wang, H. H., Lai, Y. T., and Li, J. C., 2006, "Unit-Price-Based Model for Evaluating Competitive Bids, *International Journal of Project Management*, Vol. 24, No. 2, pp. 156-166.

Yang, J. B., and Wang, W. C., 2003, "Contractor Selection by the Most Advantageous Tendering Approach in Taiwan," *Journal of the Chinese Institute of Engineers*, Vol. 26, No. 3, pp. 381-387.

Manuscript Received: Feb. 09, 2006
Revision Received: Jan. 09, 2007
and Accepted: Feb. 02, 2007