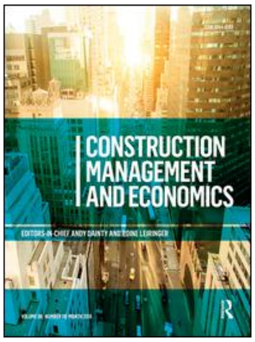

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Detection and prevention of unbalanced bids

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Unbalanced bidding is a serious problem for the construction owner because it may increase the cost of construction The most common way to mathematically unbalance a bid is frontloading where a bidder overstates the unit price of line items scheduled to be performed early in the project and understates the unit price of line items performed later. A bidder can also overstate the unit price of a line item whose quantity was somehow underrated by the engineer. If the owner proves that a mathematically unbalanced bid costs more to perform, the bid is said to be materially unbalanced, in which case the owner can reject the bid. A model is presented that formalizes and automates the process of detecting mathematically and materially unbalanced bids by comparing line item prices with the engineer's estimates and the average prices offered by the bidders. This model allows owners to detect and reject unbalanced bids, and deters bidders from unbalancing their bid.

Keywords: Bids, mathematical models, financial management, construction costs, optimization.

Introduction

Unbalanced bids constitute a serious problem for construction owners. In competitive bidding, awarding a contract to an unbalanced bid may cause the owner's overall project cost to get higher. In some cases, it generates contentious change orders (Manzo, 1997). The owner has the right to reject unbalanced bids, but it is hard to detect unbalancing. While Stark's (1968, 1972, 1974) linear programming model of unbalancing bids in highway construction contracts is relatively easy to detect by the owner, Nassar's (2004) research aims to unbalance a bid and not be caught in the process. Cattell *et al*. (2007) summarize methods of unbalancing bids and argue that a client is given full information of a contractor's item pricing and that the client is given the choice to select among the contractor's competitors, implying that there are no ethical implications of unbalancing a bid. In other words, if an owner suffers the high cost of an unbalanced bid, it is rather the owner's fault for selecting the contractor who unbalanced the bid, not the fault of contractor who unbalanced the bid. However, according to a survey of 270 owners, architects, engineers, construction managers, general contractors and subcontractors about ethical practices in the construction industry conducted by the Fails Management Institute (FMI) for the Construction Management Association of America (CMAA), unbalancing a bid was accepted as unethical by 84% of the respondents (Doran, 2004). Also, Choi (2004) considers unbalancing a bid to 'border on unethical' (p. 206) and New York City's *Procurement Ethics Guide* (New York City, 2002) specifically asks contractors not to engage in unbalanced bidding. But very few researchers have explored the ways of preventing unbalanced bids. For example, Wang's (2004) research aimed to detect the out-of-range unit prices submitted by the lowest bidder, but did not attempt to evaluate the effects of those out-of-range unit prices on future total cost.

After a description of the forms and implications of unbalancing bids, a review is presented of current practices by some state and federal agencies in the US in relation to detecting unbalanced bids. A model is then proposed that formalizes the detection of unbalanced bids and that automates the process, allowing the owner to reject unbalanced bids with confidence, hence deterring bidders from unbalancing their bids.

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Unbalanced bidding

Since unit price contracts are awarded on the basis of low bids, it is difficult to challenge the low bidders on the validity of their unit prices except for obvious unbalanced bidding. A mathematically unbalanced bid is a bid that contains some line items' unit price determined to be significantly overstated or understated. This can be determined by comparing the unit price of the line item with the engineer's estimate, the unit prices quoted by the other bidders, or other historical data of costs. According to the Federal Highway Administration (FHWA) guidelines reported by Heinz (1988), the meaning of a mathematically unbalanced bid is 'one containing lump sum or unit bid items which do not reflect reasonable actual costs plus a reasonable proportionate share of the bidder's anticipated profit, overhead costs, and other indirect costs'.

If a mathematically unbalanced bid is detected, the bid has to be further analysed to determine whether it is also materially unbalanced. A materially unbalanced bid is a mathematically unbalanced bid that may cost more money to the owner. According to Heinz's (1988) interpretation of FHWA guidelines, the materially unbalanced bid is defined as a bid which generates 'a reasonable doubt that award to the bidder submitting a mathematically unbalanced bid will result in the lowest ultimate cost to the Government'.

Frontloading is the most common way to unbalance a bid. Frontloading refers to increasing unit prices on items to be completed in the early period of the project and decreasing the unit prices on items that are to be completed in the later stages. The main purpose of frontloading on the part of the contractor is to relieve the financial problems that contractors face early in the project such as the initial expenses of mobilization and setting up. But if a contractor is set to be paid out in the early stages of the project, the owner ends up paying more when the time value of money is taken into consideration (McGreevy, 2002). For example, the bidder whose offer is presented in Table 1 appears to have inflated the cost of early activities such as the 'site clearing' and 'mobilization' items when compared with the cost of the very same items offered by another bidder whose offer is presented in Table 2. The bidder in Table 1 also deflated the cost of other items that are to be carried out later in the project such as 'concrete' and 'asphalt'. This balancing operation allows the bidder to make a bottom-line offer that is still competitive.

In the example presented in Tables 1 and 2, the offer of the lowest bidder is lower than the second lowest bidder by \$472 830 – \$470 610 = \$2220. But if the time value of money is considered with a discount rate of 1% compounded monthly, the present worth of the offers can be calculated as follows:

$$\begin{aligned}&PW_1(1\%) = \$120\,000(P/F, 1\%, 3) + \$25\,000(P/F, 1\%, 4\\&+\$12\,660(P/F, 1\%, 5) + \$108\,000(P/F, 1\%, 6)\\&+\$97\,500(P/F, 1\%, 7) + \$107\,000(P/F, 1\%, 8)\\&= \$444\,009.24\end{aligned}$$

Table 1 Bid submitted by the lowest bidder

Item	Unit price	No. of units	Total cost	Time of payment
Site clearing	\$2000/day	60 days	\$120 000	End of the 3rd month
Mobilization	\$1200/day	10 days	\$25 000	End of the 4th month
Fencing	\$30/yard	422 yards	\$12 660	End of the 5th month
Formwork	\$9/feet^2	12 000 feet^2	\$108 000	End of the 6th month
Concrete	\$150/yard^3	650 yard^3	\$97 500	End of the 7th month
Asphalt	\$12/feet^2	10 000 feet^2	\$107 000	End of the 8th month
Sum (bid price)			\$470 610	

Table 2 Bid submitted by the second lowest bidder

Item	Unit price	No. of units	Total cost	Time of payment
Site clearing	\$500/day	60 days	\$30 000	End of the 3rd month
Mobilization	\$800/day	10 days	\$8000	End of the 4th month
Fencing	\$15/yard	422 yards	\$6330	End of the 5th month
Formwork	\$12/feet^2	12 000 feet^2	\$144 000	End of the 6th month
Concrete	\$250/yard^3	650 yard^3	\$162 500	End of the 7th month
Asphalt	\$13/feet^2	10 000 feet^2	\$122 000	End of the 8th month
Sum (bid price)			\$472 830	

$$PW_2(1\%) = \$30\,000\,(P/F, 1\%, 3) + \$8000\,(P/F, 1\%, 4)$$
$$+\$6330\,(P/F, 1\%, 5) + \$144\,000\,(P/F, 1\%, 6)$$
$$+\$162\,500\,(P/F, 1\%, 7) + \$125\,000\,(P/F, 1\%, 8)$$
$$= \$442\,700.55$$

where PW_1 and PW_2 denote the present worth of the offers of the lowest bidder and the second lowest bidder, respectively. The monthly payments are multiplied by the appropriate present worth factor (P/F, i, n) where 'i' is the discount rate and 'n' the number of months between the start of the contract and the time of payment.

The present value of the offer quoted by the second lowest bidder ($442 700.55) appears to be lower than the present value of the lowest bidder's offer ($444 009.24). It can be concluded from this calculation that the lowest offer is not the best choice as far as the time value of money is concerned because the bidder who made the lowest offer appears to have frontloaded the bid, the result of which is a materially unbalanced bid.

Unbalanced bids may also occur if a bidder discovers a line item whose quantity is underestimated by the owner's engineer. A high unit price on that item and a commensurate decrease of the unit price of another line item may keep the bottom line competitive but will increase the contractor's profits. Cattell *et al.* (2007) call this procedure 'quantity error exploitation' or 'individual rate loading'. For example, the Florida DOT design plans estimated that 500 feet of sheeting was needed to support a trench while drainage pipes were installed (*Review of the FDOT Construction Bid and Contract Administration Process*, 1997). However, the successful contractor used 1729 feet of sheeting to complete the job, more than three times the amount estimated by the design plans. The successful contractor had bid a unit price of $420 per foot for the sheeting compared to $171 per foot average bid submitted by other contractors who bid on the project. As a result, the contractor was paid more than $500 000 for the additional sheeting. FDOT would have paid only $200 000 for the additional sheeting if it had the average unit price bid by other contractors. FDOT thus paid a premium of $300 000 for the additional sheeting. In another project, the design plans specified that 10 impact attenuator modules (plastic barrels of sand) would be needed to separate the construction area from the roadway on a resurfacing project. However, the contractor used 125 modules to implement the project. The contractor had bid a unit price of $1297 per module, compared to $247 average price bid per module by other bidders. As a result, FDOT had to pay a premium of $121 000 for the additional units of those line items.

According to Green (1989) and Cattell *et al.* (2007), back-end loading is also used by some bidders in inflationary environments to take advantage of escalation clauses in contracts. This method of unbalancing is not common in relatively short projects undertaken in countries like the US where the rate of inflation is low.

In analysing bids, FHWA recommends that the following process presented in Figure 1 be considered (FHWA, 2004):

- The owner should find out if the bid is *mathematically* unbalanced, i.e., whether the unit bid prices are in reasonable agreement with the engineer's estimate and/or the unit prices in other bids. A mathematically unbalanced bid occurs either because the bidder frontloaded the proposal or because the bidder adjusted the unit prices in response to a potentially larger quantity in a line item.
- The owner should find out if the bid is *materially* unbalanced, i.e., whether the bid increases the total project cost if it is awarded. The owner should consider the detrimental effect of unbalanced bidding upon the competitive process or upon contract administration after award.

Unbalanced bid analysis

In 2004, the American Association of State Highway and Transportation Officials (AASHTO) initiated a survey of unbalanced bids (AASHTO, 2004). Twenty-seven state departments of transportation (DOT) responded to this survey. Many state DOTs (such as Illinois, Kansas, Massachusetts and Connecticut)

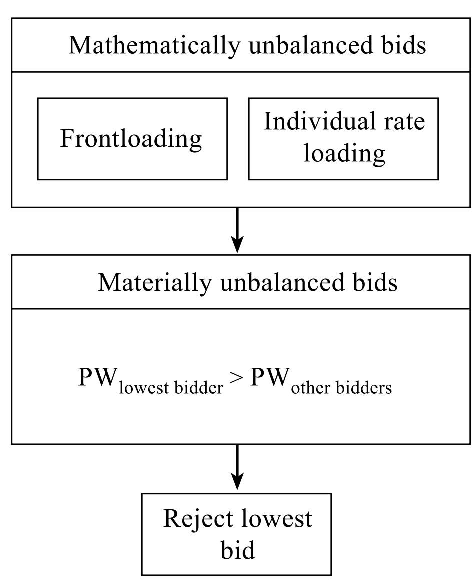

Figure 1 Detection of an unbalanced bid

discovered unbalanced bids without having in place any formal procedure to detect such occurrences. Some states quoted their standard contracts that specify the consequences of unbalancing bids, or submittingirregular proposals. Seven state DOTs, including California, Florida, North Carolina, Nevada, Tennessee, Texas and Wisconsin provided formal procedures for evaluating bids to detect unbalanced bids. The procedures used by some of these DOTs do not publicly specify the specific parameter and the acceptable ranges used in the evaluation, such as the acceptable difference between a line item's cost and the engineer's estimate, or the acceptable difference between a line item's cost and the average cost of that line item. However, as can be seen below, bidders in some states do have access to these parameters and the acceptable ranges.

- Florida DOT's procedure includes the use of an 'Unbalanced Bid Item' program that utilizes a bell curve distribution to develop a statistical average unit price for comparison purposes (*Review of the FDOT Construction Bid and Contract Administration Process*, 1997). The program then establishes a range of acceptable unit prices of the line items to compare to the unit prices submitted by bidders. If the unit prices of any line items of the bidders are out of a defined range, they are flagged by the program. The quantities of the flagged line items are rechecked by engineers to make sure they are not materially unbalanced by the bidder.
- Texas DOT detects unbalanced bids by identifying line item prices that are significantly different from the engineer's estimate. Texas DOT defines a range of 100% above or 50% below the engineer's estimate for major items, and 200% above or 75% below the engineer's estimate for minor items. Major items are defined as items that cost more than 5% of the contract value. The analysis used by Texas DOT calculates the monthly payments of the lowest bidder based on an assumed schedule. These payments are compared to the estimated monthly payments calculated by using the offer of the second lowest bidder. If the payments to the lowest bidder result in loss of interest to the State in an amount greater than the difference in the lowest and the second lowest bidder, the bid is considered to be potentially unbalanced, as it may not result in the lowest overall cost to the state.
- North Carolina DOT has a contractual provision that singles out unit prices that are in excess of a reasonable unit price. The reasonable unit price is the average of the engineer's estimate and the individual prices received from the other bidders. North Carolina DOT believes that this regulation provides a significant disincentive for unbalancing bids.
- Wisconsin DOT's *Construction and Material Manual* (2007) recommends using unbalanced bid analysis procedures if the department becomes aware of an error in a quantity of an item shown in the bidding documents, and if an item is found to be both significant to the contract and significantly unbalanced. An individual item is considered to be significant to the contract if the difference between the total cost of the item and the estimate, expressed as a percentage of the estimated total contract cost, is greater than or less than 0.50% for contracts of less than $2 million and greater than or less than 0.25% for contracts of $2 million and larger. An item is considered to be significantly unbalanced if the difference between the low bidder's unit price and the estimate, expressed as a percentage of the estimate, is greater than 50% or is less than 75%. The unbalanced bid analysis consists of (a) reviewing the line items whose estimated unit prices are identified as being significantly unbalanced; (b) checking and verifying the quantities of all items that are found to be significant to the contract; (c) calculating a gross sum for each bidder by correcting the quantities of items known to be incorrect and multiplying the corrected quantities by the unit prices offered by each contractor; (d) comparing the calculated gross sum totals of all bidders; and (e) considering the proposal of the lowest bidder to be materially unbalanced if the calculated gross sum of the contract offered by the lowest bidder is found to be higher than the calculated gross sum offered by the second lowest bidder. If the initial proposal of the lowest bidder is found to be materially unbalanced and rejected, the Department may award the contract to the next lowest bidder or consider the consequences of re-letting the project.

According to FHWA guidelines (FHWA, 2004), the detection of unbalanced bids may be facilitated by the use of computer software named Bid Analysis and Management System/Decision Support System (BAMS/DSS). Among other things, BAMS maintains historical data relating to construction contracts, generates bid-based prices for estimation systems, and analyses price and quantity of bid items by using regression and average values. If the low bid is materially unbalanced, the owner must take the appropriate action to protect the owner's interest. The law allows for the disqualification of such bids.

Detection and prevention of unbalanced bids

Because the extra cost of an unbalanced bid cannot be justified by the owner, and because owners have the right to legally reject unbalanced bids, owners should be able to stop and prevent unbalanced bids. A bidder's line item prices can be compared to the engineer's estimates to see if there are significant differences, an indication that the bid is potentially unbalanced. One can also compare a bidder's line item prices to the average line item prices of all bidders. Two separate models are therefore proposed and are described below. Since unbalancing can take the form of frontloading or adjusting the unit price of a line item whose quantity was understated by the engineer, both models are designed to deal with these situations. Both models are completely automated using MS Excel.

The proposed methodology is presented in Figures 2 and 3. Once all the bids are received from the bidders, the bottom-line offers are compared with each other. Assuming that the bidders are qualified, the lowest offer is a candidate for contract award.

Starting from the first line item, the prices of each line item in the lowest offer are compared with the engineer's estimates (Figure 2) or the average prices of the respective items in all bids (Figure 3). If the differences are within acceptable limits, this bid is not unbalanced. The limits can be set by the owner depending on the type of project and the historical precedents. As mentioned earlier, Texas DOT has defined different limits for major and minor line items, while Wisconsin DOT's limits are based on project size.

If the price difference for an item is beyond the acceptable limit, the analyst needs to check whether the quantity of the item was understated by the engineer.

- If the price of a line item is inflated by the bidder compared to the engineer's estimate (or the average prices of all bids) and the quantity involved in the line item was somehow understated by the

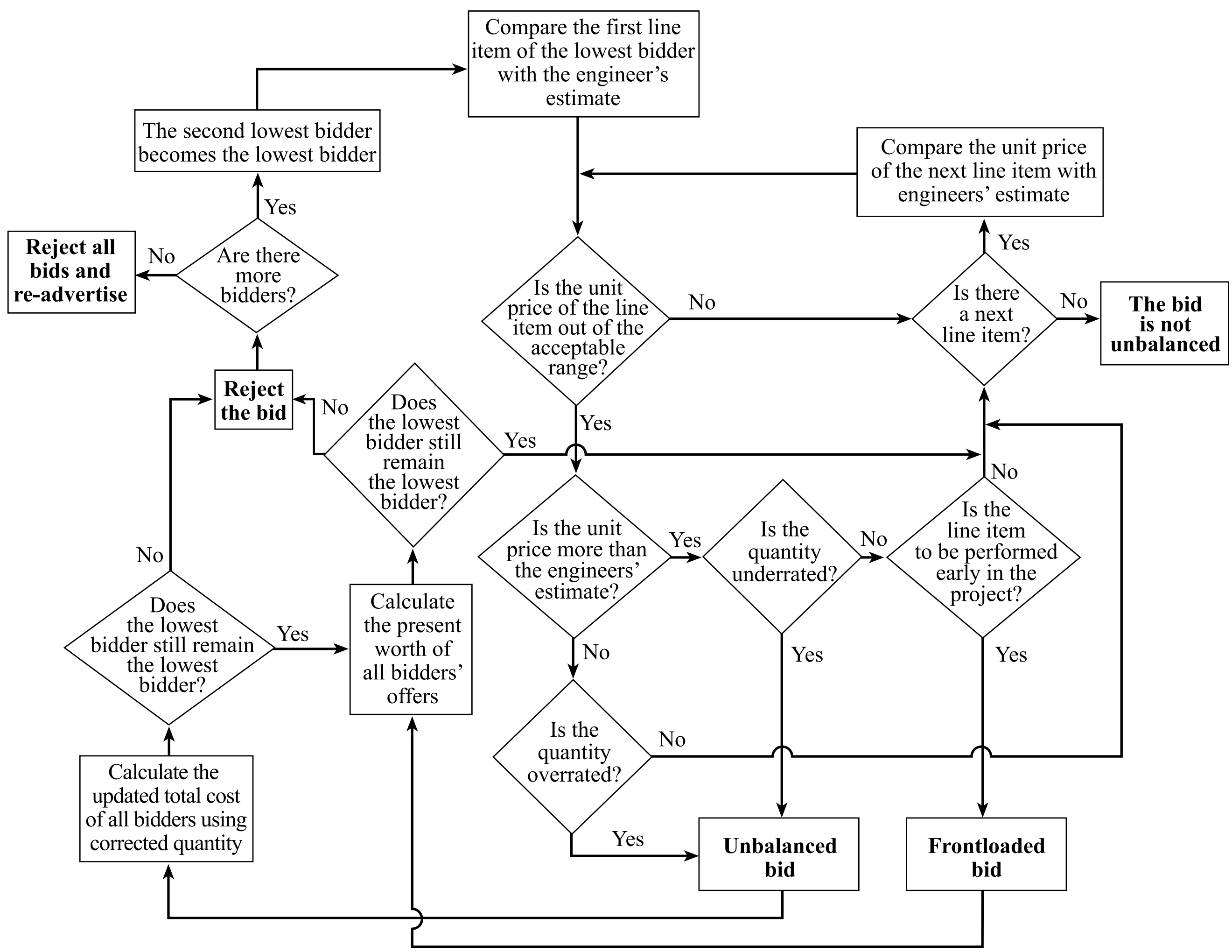

Figure 2 Detection and analysis of unbalanced bids using the engineer's estimates

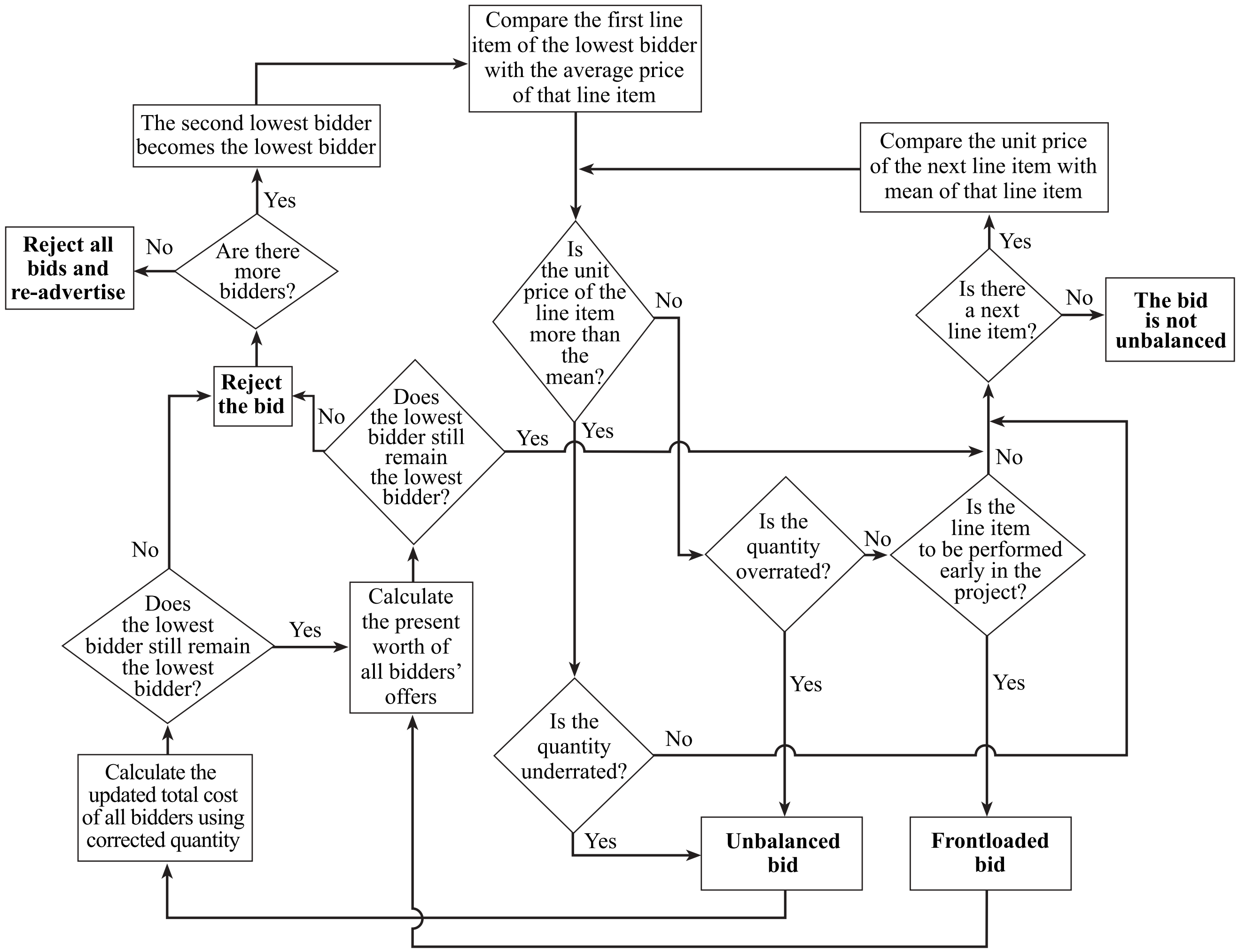

Figure 3 Detection and analysis of unbalanced bids using average unit prices

engineer, this bid is *mathematically* unbalanced. In such cases, it is justified for the owner to recalculate the bids using the new (bigger) quantities but the same unit prices originally proposed by the bidders in order to establish if the lowest bid is *materially* unbalanced. If after recalculating the bids using the new quantities but the original unit prices proposed by the bidders, the original lowest bidder remains the lowest bidder, the contract is awarded to this bidder. But if the original lowest bidder is not the lowest bidder any more, then the original lowest bid is rejected on the basis that it was mathematically and materially unbalanced. The next lowest bidder becomes the new candidate for award of contract. The process described in this bullet point is repeated until an award is made or all bidders are exhausted, in which case the bid is re-advertised.

- If the price of a line item is inflated by the bidder compared to the engineer's estimate (or the average prices of all bids) and there are no doubts about the quantity involved in the line item, then the analyst needs to check if this bid was frontloaded. If the line item is scheduled early in the project, then the bid is frontloaded, i.e., it is *mathematically* unbalanced. The analyst then needs to check if this frontloading affects the present worth of the payments to the contractor by using an appropriate work schedule, discount rate, and economic analysis principles. If after calculating the present worth of the payments, the original lowest bidder remains the lowest bidder, the contract is awarded to this bidder. But if the original lowest bidder is no longer the lowest bidder, then the original lowest bid is rejected on the basis that it was mathematically and materially unbalanced. The next lowest bidder becomes the new candidate for award of contract. The process described in this bullet point is repeated until an award is made or all bidders are exhausted, in which case the bid is re-advertised. Back-end loading is not considered in this study because it is not likely to take place in the current low inflation environment in the US.

The process was automated by using an Excel spreadsheet such as the one in Table 3 that shows the line items, the engineer's quantities, an approximate payment schedule, the engineer's estimate of cost, the acceptable limits and each bidder's offers relative to each line item. The program orders the bids from the lowest to the highest offer, Bidder 1 being the lowest offer, and highlights the line items in Bidder 1's offer whose prices are beyond the acceptable limits (shown with asterisks in Table 4). The analyst checks the quantities involved in these line items and replaces them with the correct quantities if any were understated. The program recalculates the bids of all bidders using the new quantities and orders them again from the lowest to the highest offer. If the original lowest bidder is no longer the lowest offer, it is rejected on the grounds that the bid was materially unbalanced.

If the original lowest bidder is still the lowest bidder, the program checks for frontloading (Table 5). It first marks with an asterisk the line items whose price is substantially higher than the engineer's estimate (or the average price of all bidders) and whose performance is scheduled early in the project. The timing of 'early' is specified by the analyst. It then calculates the present worth of all payments given the approximate schedule specified in Table 3 (column 3) and an appropriate discount rate input by the analyst. The present worth of the scheduled payments to all the bidders is calculated and presented in the bottom row of the spreadsheet (Table 6), where the changes in the order of the bids become apparent (marked with an asterisk). In the example presented in Table 6, Bid 1 appears to have been frontloaded and Bid 5 appears to generate the lowest present worth of payments.

Discussion of the proposed models

The two models proposed here compare a bidder's line item prices (1) to the engineer's estimates; or (2) to the average line item prices of all bidders. Neither model is perfect as the engineer's estimates and the average line item prices may not constitute exact measures of the true value of the line items. Indeed, the engineer's estimate may at times be quite inaccurate (Beeston, 1999), and average line item prices may be skewed by several unbalanced bids in the same batch. It should also be noted that the individual line item prices proposed by the bidders are also estimates and as such add to the uncertainty inherent in the process. It follows that both models are approximate but may still yield useful information if the models' parameters are set intelligently by the analyst. In the first model, if the owner is confident that the engineer's estimates are accurate, the owner may look for unbalanced bids by looking into line items whose prices display a relatively small variance from the engineer's estimate. On the other hand, if the owner has doubts about the accuracy of the engineer's estimate, then the search for an unbalanced bid is to be conducted by looking for a relatively larger variance from the engineer's estimate. The second model where a bidder's line item prices are compared to the average line item prices is more stable than the preceding alternative because this model makes use of the average of all bids, resulting in the dissipation of any abnormalities caused by occasional unbalanced bids in the batch. But this model relies on the analyst's input about what proportion of the project constitutes the 'early' part of the schedule. This information is necessary to detect frontloading in the 'early' portion of the project. The analyst needs also to input a discount rate, which may be difficult to do with certainty.

It seems therefore that the major limitation of the proposed system lies in the absence of clear guidelines relating to the value of the four parameters one needs to specify to run the program, namely: (1) the accepted difference from the engineer's estimate; (2) the accepted difference from the average line item prices; (3) the proportion of the project that describes 'early' schedule; and (4) the discount rate. On the other hand, one should note that the ability to input these parameters is an advantage in that it allows an analyst to conduct what-if analyses, particularly with respect to the last two parameters.

Conclusion

Unbalanced bidding is a serious problem for the construction owner. Unbalancing a bid is considered by many as unethical. Unbalanced bids can be rejected if caught by the owner. If awarded, the cost of these contracts to the owner is unjustifiably increased. Despite these facts, most researchers appear to be interested in the optimization of a contractor's cash flow by unbalancing a bid and how not to be caught in the process (e.g. Nassar, 2004; Cattell *et al.*, 2007). Detecting an unbalanced bid is normally difficult and has become even more difficult thanks to the efforts of these researchers. Given the current literature that aggressively tries to teach contractors the various methods of unbalancing a bid without getting caught, it is time to provide a sensible tool that allows owners to detect and reject unbalanced bids.

Table 3 Start-up spreadsheet of bid analysis using the engineer's estimates

Bid item no.	Quantity	Payment schedule	Engineer's estimate	% of price range	Upper limit	Lower limit	Bidder 1	Bidder 2	Bidder 5	Bidder 4	Bidder 3
100	29	24	15 000.00	20%	18 000.00	12 000.00	5000.00	16 394.00	17 589.00	16 554.00	16 217.00
101	14	19	35 000.00	20%	42 000.00	28 000.00	34 538.00	5000.00	33 431.00	34 240.00	32 326.00
102	12	18	20 000.00	20%	24 000.00	16 000.00	18 552.00	18 704.00	19 486.00	20 335.00	19 609.00
103	30	3	80 000.00	20%	96 000.00	64 000.00	90 000.00	69 923.00	69 380.00	72 040.00	67 827.00
104	6	1	300 000.00	20%	360 000.00	240 000.00	600 000.00	450 000.00	300 000.00	306 527.00	324 964.00
105	12	24	1200.00	20%	1440.00	960.00	1132.00	1059.00	1006.00	946.00	1006.00
106	30	25	89 000.00	20%	106 800.00	71 200.00	40 000.00	50 000.00	88 806.00	87 769.00	96 949.00
107	14	22	4500.00	20%	5400.00	3600.00	4760.00	4515.00	4501.00	4533.00	4313.00
108	25	13	62 000.00	20%	74 400.00	49 600.00	61 587.00	67 031.00	73 251.00	70 689.00	71 043.00
109	25	3	100 000.00	20%	120 000.00	80 000.00	98 816.00	140 000.00	109 241.00	110 383.00	113 937.00
110	7	9	5000.00	20%	6000.00	4000.00	4957.00	4894.00	4350.00	4433.00	4487.00
111	30	17	3400.00	20%	4080.00	2720.00	3674.00	3759.00	3313.00	3505.00	3501.00
112	2	16	150 000.00	25%	187 500.00	112 500.00	20 000.00	172 000.00	165 000.00	170 000.00	165 000.00
113	16	9	2800.00	25%	3500.00	2100.00	2979.00	3114.00	2751.00	3005.00	3212.00
114	18	9	7200.00	25%	9000.00	5400.00	7851.00	8510.00	8078.00	8178.00	8780.00
115	5	8	3600.00	25%	4500.00	2700.00	3485.00	3278.00	3134.00	3005.00	3153.00
116	32	25	9800.00	25%	12 250.00	7350.00	9131.00	9573.00	11 064.00	11 170.00	10 217.00
Total cost							13 124 973.00	13 336 015.00	13 413 891.00	13 482 422.00	13 766 763.00

Table 4 Detecting differences in item prices and quantities using the engineer's estimates

Bid item no.	Quantity	Payment schedule	Engineer's estimate	% of price range	Upper limit	Lower limit	Bidder 1	Bidder 2	Bidder 5	Bidder 4	Bidder 3
100	29	24	15 000.00	20%	18 000.00	12 000.00	5000.00*	16 394.00	17 589.00	16 554.00	16 217.00
101	14	19	35 000.00	20%	42 000.00	28 000.00	34 538.00	5000.00	33 431.00	34 240.00	32 326.00
102	12	18	20 000.00	20%	24 000.00	16 000.00	18 552.00	18 704.00	19 486.00	20 335.00	19 609.00
103	30	3	80 000.00	20%	96 000.00	64 000.00	90 000.00	69 923.00	69 380.00	72 040.00	67 827.00
104	6	1	300 000.00	20%	360 000.00	240 000.00	600 000.00**	450 000.00	300 000.00	306 527.00	324 964.00
105	12	24	1200.00	20%	1440.00	960.00	1132.00	1059.00	1006.00	946.00	1006.00
106	30	25	89 000.00	20%	106 800.00	71 200.00	40 000.00*	50 000.00	88 806.00	87 769.00	96 949.00
107	14	22	4500.00	20%	5400.00	3600.00	4760.00	4515.00	4501.00	4533.00	4313.00
108	25	13	62 000.00	20%	74 400.00	49 600.00	61 587.00	67 031.00	73 251.00	70 689.00	71 043.00
109	25	3	100 000.00	20%	120 000.00	80 000.00	98 816.00	140 000.00	109 241.00	110 383.00	113 937.00
110	7	9	5000.00	20%	6000.00	4000.00	4957.00	4894.00	4350.00	4433.00	4487.00
111	30	17	3400.00	20%	4080.00	2720.00	3674.00	3759.00	3313.00	3505.00	3501.00
112	2	16	150 000.00	25%	187 500.00	112 500.00	20 000.00*	172 000.00	165 000.00	170 000.00	165 000.00
113	16	9	2800.00	25%	3500.00	2100.00	2979.00	3114.00	2751.00	3005.00	3212.00
114	18	9	7200.00	25%	9000.00	5400.00	7851.00	8510.00	8078.00	8178.00	8780.00
115	5	8	3600.00	25%	4500.00	2700.00	3485.00	3278.00	3134.00	3005.00	3153.00
116	32	25	9800.00	25%	12 250.00	7350.00	9131.00	9573.00	11 064.00	11 170.00	10 217.00
Total cost							13 124 973.00	13 336 015.00	13 413 891.00	13 482 422.00	13 766 763.00

Notes: * Line item cost below acceptable range; ** line item cost beyond acceptable range.

Table 5 Detecting frontloading using the engineer's estimates

Bid item no.	Quantity	Payment schedule	Engineer's estimate	% of price range	Upper limit	Lower limit	Bidder 1	Bidder 2	Bidder 5	Bidder 4	Bidder 3
100	29	24	15 000.00	20%	18 000.00	12 000.00	5000.00	16 394.00	17 589.00	16 554.00	16 217.00
101	14	19	35 000.00	20%	42 000.00	28 000.00	34 538.00	5000.00	33 431.00	34 240.00	32 326.00
102	12	18	20 000.00	20%	24 000.00	16 000.00	18 552.00	18 704.00	19 486.00	20 335.00	19 609.00
103	30	3	80 000.00	20%	96 000.00	64 000.00	90 000.00	69 923.00	69 380.00	72 040.00	67 827.00
104	6	1	300 000.00	20%	360 000.00	240 000.00	600 000.00*	450 000.00	300 000.00	306 527.00	324 964.00
105	12	24	1200.00	20%	1440.00	960.00	1132.00	1059.00	1006.00	946.00	1006.00
106	30	25	89 000.00	20%	106 800.00	71 200.00	40 000.00	50 000.00	88 806.00	87 769.00	96 949.00
107	14	22	4500.00	20%	5400.00	3600.00	4760.00	4515.00	4501.00	4533.00	4313.00
108	25	13	62 000.00	20%	74 400.00	49 600.00	61 587.00	67 031.00	73 251.00	70 689.00	71 043.00
109	25	3	100 000.00	20%	120 000.00	80 000.00	98 816.00	140 000.00	109 241.00	110 383.00	113 937.00
110	7	9	5000.00	20%	6000.00	4000.00	4957.00	4894.00	4350.00	4433.00	4487.00
111	30	17	3400.00	20%	4080.00	2720.00	3674.00	3759.00	3313.00	3505.00	3501.00
112	2	16	150 000.00	25%	187 500.00	112 500.00	20 000.00	172 000.00	165 000.00	170 000.00	165 000.00
113	16	9	2800.00	25%	3500.00	2100.00	2979.00	3114.00	2751.00	3005.00	3212.00
114	18	9	7200.00	25%	9000.00	5400.00	7851.00	8510.00	8078.00	8178.00	8780.00
115	5	8	3600.00	25%	4500.00	2700.00	3485.00	3278.00	3134.00	3005.00	3153.00
116	32	25	9800.00	25%	12 250.00	7350.00	9131.00	9573.00	11 064.00	11 170.00	10 217.00
Total cost							13 124 973.00	13 336 015.00	13 413 891.00	13 482 422.00	13 766 763.00

Note: *Line item cost substantially higher than the engineer's estimate (or the average price of all bidders).

Table 6 Economic analysis

Bid item no.	Quantity	Payment schedule	Engineer's estimate	% of price range	Upper limit	Lower limit	Bidder 1	Bidder 2	Bidder 5*	Bidder 4	Bidder 3
100	29	24	15 000.00	20%	18 000.00	12 000.00	5000.00	16 394.00	17 589.00	16 554.00	16 217.00
101	14	19	35 000.00	20%	42 000.00	28 000.00	34 538.00	5000.00	33 431.00	34 240.00	32 326.00
102	12	18	20 000.00	20%	24 000.00	16 000.00	18 552.00	18 704.00	19 486.00	20 335.00	19 609.00
103	30	3	80 000.00	20%	96 000.00	64 000.00	90 000.00	69 923.00	69 380.00	72 040.00	67 827.00
104	6	1	300 000.00	20%	360 000.00	240 000.00	600 000.00	450 000.00	300 000.00	306 527.00	324 964.00
105	12	24	1200.00	20%	1440.00	960.00	1132.00	1059.00	1006.00	946.00	1006.00
106	30	25	89 000.00	20%	106 800.00	71 200.00	40 000.00	50 000.00	88 806.00	87 769.00	96 949.00
107	14	22	4500.00	20%	5400.00	3600.00	4760.00	4515.00	4501.00	4533.00	4313.00
108	25	13	62 000.00	20%	74 400.00	49 600.00	61 587.00	67 031.00	73 251.00	70 689.00	71 043.00
109	25	3	100 000.00	20%	120 000.00	80 000.00	98 816.00	140 000.00	109 241.00	110 383.00	113 937.00
110	7	9	5000.00	20%	6000.00	4000.00	4957.00	4894.00	4350.00	4433.00	4487.00
111	30	17	3400.00	20%	4080.00	2720.00	3674.00	3759.00	3313.00	3505.00	3501.00
112	2	16	150 000.00	25%	187 500.00	112 500.00	20 000.00	172 000.00	165 000.00	170 000.00	165 000.00
113	16	9	2800.00	25%	3500.00	2100.00	2979.00	3114.00	2751.00	3005.00	3212.00
114	18	9	7200.00	25%	9000.00	5400.00	7851.00	8510.00	8078.00	8178.00	8780.00
115	5	8	3600.00	25%	4500.00	2700.00	3485.00	3278.00	3134.00	3005.00	3153.00
116	32	25	9800.00	25%	12 250.00	7350.00	9131.00	9573.00	11 064.00	11 170.00	10 217.00
Total cost							13 124 973.00	13 336 015.00	13 413 891.00	13 482 422.00	13 766 763.00
Total cost considering the time value of money							12 211 697.05	12 288 764.35	12 041 276.13	12 120 057.38	12 358 160.47

Note: *Bidder with lowest present worth value.

FHWA and a number of state DOTs in the US have spelled out general principles to protect their interests with respect to unbalanced bids. Many DOTs routinely but informally check bids for unbalancing using different processes. Some DOTs such as the ones in Florida, Texas, North Carolina and Wisconsin have a formal process in place but each uses different approaches and different assumptions. The proposed model represents a marked improvement on existing practice because it is an attempt to develop a thorough methodology that systematically covers all aspects of unbalancing a bid. The proposed model is fully automated. It institutionalizes the process of detecting unbalanced bids and is expected to deter bidders from unbalancing their bids.

The proposed model can be improved by further research into developing guidelines for the acceptable difference between the engineer's estimate and the estimate proposed by the bidder for any line item, and the acceptable difference between the average of the line item prices and the prices proposed by a bidder. It is also recommended that the owner keep bid price and final cost data in a database for future reference in tracking over-run and under-run trends in every bid item.

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