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OPTIMUM BID PRICES MODEL FOR ALLOCATION RATES TO UNIT PRICE CONTRACT

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Abstract:
The unit price contract prepared by the client indicates contract items and estimated quantities deemed necessary to accomplish the proposal objective. Moreover, the bidder is required to allocate unit prices for these unit bids. This paper presents a model concerning the formulation of tendering unit bids for unit price contract. The proposed model attempts to objectively exploit variation trends in client-provided quantities for the allocation of rates to unit bids in attempt to achieve the maximum benefit for bidder. Often the unbalance in distributing the items markup of the tender would result unreasonable unit prices. The proposed model has been devised to determine the unit bids of the unit price proposals in order to give reasonable unit prices and also maximize the expected profit. The model is especially useful for mega and complicated projects of many items. Finally, the developed model has the remarkable feature that, for given project information, no other means of unbalancing will yield a greater expected profit under the given constraints.

Keywords: bidding strategies, unbalanced bidding, unit price contract, genetic algorithms, operations research.

ملخص البحث

عقد تسعير الوحدة المعد من قبل المالك يشير إلى بنود العقد والكميات المقدرة تم حصرها بصفة تقريبية لإنجاز العمل المطلوب، ويتعين علي مقدم العطاء تقديم أسعار الوحدة لكل بند من بنود العطاء. الورقة الحالية تقدّم نموذجاً لتسعير الوحدات في المناقصات الخاصة بعقود تسعير الوحدة. والنموذج المقترح بهذه الورقة يحاول هادفاً الإستفادة من الاختلافات في الكميات المقدرة من قبل المالك في عملية تسعير البنود لتعظيم أقصى فائدة لمقدم العطاء. فغالباً ما يلجأ مقدم العطاء إلى عدم التوازن في التوزيع لأسعار البنود للعقد مما ينتج عنه عدم منطقية وعدم واقعية لهذه الأسعار المقترحة. وتبعاً لذلك، فقد اقترح نموذجاً رياضياً بواسطة الباحث لتحديد أسعار البنود المختلفة لعقود تسعير الوحدة بغرض تحقيق أقصى منفعة لمقدم العطاء ودرءاً للعيوب السابق ذكرها. إنّ النموذج المقترح مفيد وبصفة خاصة في المشاريع الضخمة والمعقّدة التي تشتمل على العديد من بنود الأعمال. وأخيراً، فإن هذا النموذج يتميز عن غيره بأنه عند إعطاءه البيانات المختلفة للمشروع والقيود المطلوبة لتسعير البنود، فإنه يعطي حلاً مثالياً يحقق أعلى قيمة ربح متوقعة لا يمكن الحصول عليها عن طريق أي نموذج أخر.

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1. Introduction

The competitive bidding process is the bread and butter of most general contractors. One measure of a contractor's business success is how the firm competes in its bids. The role of an optimum bid is vital in striking the optimum balance between a bid price that is as practically low as possible to win the job and as practically high as possible to maximize the profit. The total bid amount must, of course, cover a contractor's direct costs and indirect costs. For a given bid amount, a contractor can increase the expected net profit by placing higher bid prices on those items done early in a project and lower prices on those done later. This will increase the early cash flow, reduce the contractor's investment and thus yield a higher profit when the time value of money is considered. This process is called unbalancing, and is widely accepted by the construction industry as a mechanism to reduce investment and increase discounted profit. The unit price contract is characterized by a list of bid items that comprise the anticipated scope of the work. Each bid item has an associated quantity of work that represents the owner's evaluation of this item. If the actual quantity is significantly different than estimated, a contractor can be severely penalized, although renegotiation clauses generally exist to allow bid price adjustment if a significant quantity variance exists. Moreover the owner may choose to delete a bid item after the contract is awarded. This may occur because of changes in the site conditions, changes in the owner's plans, or lack of funds. Thus, the contractor must carefully assess which are the key bid items of a contract and which may be potentially deleted.

A contractor bidding on such a proposal is required to submit a bid price against each bid item. These are then extended by the owner's bid quantities to calculate the total bid amount. The lowest bidder is then generally selected to do the work. Many studies have been conducted on developing mathematical models for unbalancing bidding strategy. Tong, Y., and Lu, Y. (1992) proposed a mathematical model that examines the unbalanced contract bidding and attempts to allocate the rates to unit quantities for the benefit of the bidder. In addition, Wang, W-C. (2004) developed an electronic-based procedure for managing unbalanced bids. This procedure was built on an electronic-based bidding process for effectively and efficiently supporting, reviewing, and adjusting the bidder's proposed unit prices for a lump sum procurement project.

A recent study Cattell D., Bowen P., and Kaka A.(2007) studied the unbalanced bidding models in construction. This study concludes that further research is required to test the practical efficacy of some of the proposed unbalanced models. The preceding complications make bid price unbalancing a sensitive problem that requires much managerial experience. So, there is a need for a new unbalanced bidding method to submit the unit prices for the unit price contracts that will minimize the total bid price and maximize the total project profit.

This paper presents a new unbalanced bidding model concerning tendering formulating unit bids for unit price contract technique. The unit price contract prepared by the client indicates contract items and estimated quantities deemed necessary to accomplish the proposal objective. The bidder is required to allocate unit prices for these unit bids. The proposed model attempts to objectively exploit variation trends in client-provided quantities for the allocation of rates to unit bids for the benefit of the bidder. The proposed model was devised to determine the unit bids for the unit price proposals with the objective of maximizing the expected profit

The model uses genetic algorithm technique for optimum markup estimation that derives solutions to new unbalanced bid. The presented model is coded in a user-friendly software written in Visual Basic with the necessary interfaces. The software provides the contractor with the utility to store his own bid data in a tabular format. The capabilities of the present model are demonstrated through an example application.

2. Unbalanced Bid Model Formulation

Consider a unit price contract with n work items performed over a certain time periods. Let B_i denote the bid price of item i in balanced case, in L.E. per quantity, Let DC_i be the total direct cost for bid item i, $B_i = DC_i$ F, F = Factor for (indirect cost + markup), and UB_i the variable of unbalanced bid price of item i (assumed to be unknown), i = 1, ……... n, Let QO_i be the owner's bid quantity for bid item i and QC_i be the contractor's actual quantity for bid item i, the estimated owner's quantity may differ from the contractor's quantity, i.e. QO_i not equal QC_i.

Thus ,the objective function and the

constraints were formulated in the model as

follows :

Objective Function

The goal is to maximize the total bid price of actual bid quantities, TBPAQ:

$$TBPAQ = \sum_{i=1}^{n} QC_i \; UB_i \qquad (1)$$

Constraints

1- Bid items constraint

The contractor must set unbalanced bid prices such that the total probable bid amount will cover at least the expected direct costs.

$$UB_i \geq DC_i \qquad (2)$$

And unbalanced bid prices less than or equal $2DC_i$

$$UB_i \leq 2DC_i \qquad (3)$$

2- Total unbalanced bid price constraint

The contractor generally requires that the unbalanced bid prices fall within specified ranges, e.g., no lower than direct cost, and no higher than the total balanced bid price for estimated quantities.

$$\sum_{i=1}^{n} QO_i \; UB_i \leq \sum_{i=1}^{n} QO_i \; B_i \qquad (4)$$

3- The probability of winning the bid constraint

For maximizing the probability of winning the bid.

$$\sum_{i=1}^{n} QO_i \; UB_i \leq V \qquad (5)$$

Where ; V = value for assessing the probability of winning with bid amount

3. Proposed Computer Program

To demonstrate the operation of the proposed computer program as an unbalanced bid system, an example application is presented. The example represents a project on which the contractor is preparing a bid. In this study visual basic software is selected for implementing the genetic algorithm procedure. Using this software, the procedure was coded and then used to search for an optimum unit bids for the unit price proposals with the objective of maximizing the expected profit schedule for the case study on hand. The example project consists of five work items. The user inputs data in a tabular format as shown in the middle box of the screen shown in Fig. 1. The table size is provided for the user according to the number of bid items at the bottom box of the screen. The example-project data is shown in Table 1. The program provides vertical and horizontal scroll bars if needed, to enable filling in the whole table. Once data are entered, the contractor may print or preview the entered data to check for accuracy, save the data and then select option of unbalanced bid to show the screen in Fig. 2. This screen gives the total bid price for initial estimated quantities and prompts the user to enter the maximum bid price for estimated quantities and the genetic algorithm data (number of population, and offspring). Once data are entered, the user presses on solution button to view the screen shown in Fig. 3. This screen presents the genetic algorithms output for unbalancing bid. Moreover, it gives the balanced bid value for estimated quantities; balanced bid value for actual quantities; the unbalanced bid value for actual quantities and the unbalanced bid value for estimated quantities. Table 2 is a print out of the program that shows the model output for the example (1) (final optimum) where maximum bid value for estimated quantities ≤ 573,000 LE.

4. Program Verification

One of the major objectives of the proposed program was to design a user-friendly interface that facilitates the task of entering data and solving the optimization model especially for those who are not familiar with model formulation. This requirement entitled writing programs for executing the genetic algorithm method instead of using the available optimization softwares. In addition, another program was written to formulate the objective function and constraints of the model out of the entered project data. The genetic algorithm program was first tested using models of different sizes. The results were compared against that obtained by QSB and LINDO optimization softwares which showed identical results.

5. Free Format Integer Linear Programming Model By (QSB) Program for Example (1).

Objective Function
Maximize

$$3300X1 + 1500X2 + 2500X3 + 3700X4 + 4500X5$$

Under Constraints

1) $3000X1 + 1200X2 + 2000X3 + 3500X4 + 4000X5 \leq 573000$
2) $X1 \leq 20$ 3) $X2 \leq 60$ 4) $X3 \leq 40$
5) $X4 \leq 100$ 6) $X5 \leq 80$
7) $X1 \geq 10$ 8) $X2 \geq 30$ 9) $X3 \geq 20$
10) $X4 \geq 50$ 11) $X5 \geq 40$

6. Example Application

The first example is a project composed of 5 bid items. A list of the bid items and the initial project data are shown in table 3. The bidder decided to submit the tender with total bid price equals 573,300 LE. First, the contractor has to input number of population (50,000), number of offspring (5,000) and the maximum bid price for estimated quantities (573,300 LE). The program formulates the model objective function and constraints, solves using genetic algorithms and accordingly prompts the user with the optimum solution. Table 4 shows the optimum output values for unbalanced bid prices assignments which appears in the last column of the table. At this point, the contractor may want to change the maximum bid price for estimated quantities of the model and see how that can affect the bid items prices, the program offers this facility to the user.

The second example is a project composed of 15 bid items. A list of the bid items and the initial project data are shown in table 5. The bidder decided to submit the tender with total bid price equals 4,177,000 LE. This approach tries to arrive at quick improvements to the total bid price. In this example the genetic algorithm optimization search procedure was used to conduct three trails with different population sizes and number of offsprings. First, the contractor has to input number of population (50,000), number of offspring(5,000) and the maximum bid price for estimated quantities (4,177,000 LE). The GA approach is an efficient search procedure that arrives at solutions by searching only a small fraction of the total search space gives the results shown in table 6. To further examine the performance of the GA procedure on this project, several other trails were conducted with different population sizes 500,000 and 5,000,000. Each of these trails improved the results achieving the optimum solutions. Table 7 shows the model output values for unbalanced bid prices assignments with population size 500,000 which appear in the last column of this table. The optimum output values for unbalanced bid prices assignments appear in the last column of the table 8 by increasing population size to 5,000,000. At this point, the contractor may want to change the maximum bid price for estimated quantities of the model and see how that can affect the bid items prices, the program offers this facility to the user.

It can be seen from the results of tables 6, 7 and 8 that each trail improved the total bid value for actual quantities. In trail 1 the model output for the total bid value for actual quantities equals 4,054,100 LE, this value increased into 4,062,800 LE in trail 2. Trail 3 produced an optimum model output for the total bid value for actual quantities equals 4,109,900 LE. Based upon the results from tables 6, 7 and 8 the trails show the benefits of the genetic algorithm procedure in maximizing the expected profit by pricing the unit bids for the unit price proposals in unit price contract.

Table. 1 The initial project data

Bid Items	Estimated Quantity (EQ)	Actual Quantity (AQ)	Direct Cost(LE) (DC)	Balanced Price(LE) (BP)	**<u>Total Bid Price for Estimated Quantities (TBPEQ).</u>** TBPEQ = ∑EQ*BP = 573,300LE Bp = DC*1.3 **<u>Total Bid Price for Actual Quantities (TBPAQ).</u>** TBPAQ = ∑AQ*BP = 640,900 LE Bp = DC*1.3
1	3000	3300	10	13	
2	1200	1500	30	39	
3	2000	2500	20	26	
4	3500	3700	50	65	
5	4000	4500	40	52	

Table. 2 The Model Output for Example (1) (Final Optimum).

Bid Items	Estimated Quantity (EQ)	Actual Quantity (AQ)	Direct Cost(LE) (DC)	Balanced Price(LE) (BP)	Unbalanced Price(LE) (UP)	**<u>Total Unbalanced Bid Price for Estimated Quantities (TBPEQ).</u>** TUBPEQ = ∑EQ*UP=573,000LE UP = Output From the Model **<u>Total Unbalanced Bid Price for Actual Quantities (TBPAQ).</u>** TUBPAQ = ∑AQ*UP=651,000 LE UP = Output From the Model
1	3000	3300	10	13	10	
2	1200	1500	30	39	60	
3	2000	2500	20	26	40	
4	3500	3700	50	65	50	
5	4000	4500	40	52	54	

*Maximum Bid Value for Estimated Quantities ≤ 573,000 LE

Table. 3 The initial project data

Bid Items	Estimated Quantity (EQ)	Actual Quantity (AQ)	Direct Cost(LE) (DC)	Balanced Price(LE) (BP)	**<u>Total Bid Price for Estimated Quantities (TBPEQ).</u>** TBPEQ = ∑EQ*BP = 573,300LE Bp = DC*1.3 **<u>Total Bid Price for Actual Quantities (TBPAQ).</u>** TBPAQ = ∑AQ*BP = 586,300 LE Bp = DC*1.3
1	3000	3300	10	13	
2	1200	1000	30	39	
3	2000	2400	20	26	
4	3500	3200	50	65	
5	4000	4500	40	52	

Table. 4 The Model Output for Example (2) (Final Optimum).

Bid Items	Estimated Quantity (EQ)	Actual Quantity (AQ)	Direct Cost(LE) (DC)	Balanced Price(LE) (BP)	Unbalanced Price(LE) (UP)
1	3000	3300	10	13	10
2	1200	1500	30	39	30
3	2000	2500	20	26	40
4	3500	3700	50	65	50
5	4000	4500	40	52	63

Total Unbalanced Bid Price for Estimated Quantities (TBPEQ).
TUBPEQ = ∑EQ*UP=573,000LE
UP = Output From the Model

Total Unbalanced Bid Price for Actual Quantities (TBPAQ).
TUBPAQ = ∑AQ*UP=602,500LE
UP = Output From the Model

*Maximum Bid Value for Estimated Quantities ≤ 573,300 LE

Table. 5 The initial project data

Bid Items	Estimated Quantity (EQ)	Actual Quantity (AQ)	Direct Cost(LE) (DC)	Balanced Price(LE) (BP)
1	3000	3300	10	13
2	1200	1500	30	39
3	2000	1800	20	26
4	3500	3300	50	65
5	4000	4500	80	104
6	8000	5000	100	130
7	9000	9200	20	26
8	1000	900	40	52
9	500	400	30	39
10	800	900	60	78
11	6000	5500	50	65
12	2500	2700	110	143
13	1500	1200	120	156
14	5500	6500	100	130
15	4500	4000	50	65

Total Bid Price for Estimated Quantities (TBPEQ).
TBPEQ = ∑EQ*BP = 4,178,200 LE
Bp = DC*1.3

Total Bid Price for Actual Quantities (TBPAQ).
TBPAQ = ∑AQ*BP = 3,888,300 LE
Bp = DC*1.3

Table. 6 The Model Output for Example (3) Try Number One.

Bid Items	Estimated Quantity (EQ)	Actual Quantity (AQ)	Direct Cost(LE) (DC)	Balanced Price(LE) (BP)	Unbalanced Price(LE) (UP)
1	3000	3300	10	13	10
2	1200	1500	30	39	60
3	2000	1800	20	26	23
4	3500	3300	50	65	52
5	4000	4500	80	104	150
6	8000	5000	100	130	101
7	9000	9200	20	26	20
8	1000	900	40	52	48
9	500	400	30	39	51
10	800	900	60	78	108
11	6000	5500	50	65	52
12	2500	2700	110	143	114
13	1500	1200	120	156	180
14	5500	6500	100	130	179
15	4500	4000	50	65	55

Total Unbalanced Bid Price for Estimated Quantities (TUBPEQ).
TUBPEQ = ∑EQ*UP = 4,176,900 LE
UP = Output From the Model

Total Unbalanced Bid Price for Actual Quantities (TUBPAQ).
TUBPAQ = ∑AQ*UP = 4,054,100 LE
UP = Output From the Model

*Population Size = 50,000
*Number of Offspring =500
*Maximum Bid Value for Estimated Quantities ≤ 4,177,000 LE
*Balanced Bid Value for Estimated Quantities = 4,178,200 LE
*Balanced Bid Value for Actual Quantities = 3,888,300 LE
*Model Output Bid Value for Actual Quantities = 4,054,100 LE
*Model Output Bid Value for Estimated Quantities = 4,176,900 LE

Table. 7 The Model Output for Example (3) Try Number Two.

Bid Items	Estimated Quantity (EQ)	Actual Quantity (AQ)	Direct Cost(LE) (DC)	Balanced Price(LE) (BP)	Unbalanced Price(LE) (UP)
1	3000	3300	10	13	18
2	1200	1500	30	39	60
3	2000	1800	20	26	26
4	3500	3300	50	65	54
5	4000	4500	80	104	80
6	8000	5000	100	130	101
7	9000	9200	20	26	32
8	1000	900	40	52	48
9	500	400	30	39	51
10	800	900	60	78	115
11	6000	5500	50	65	56
12	2500	2700	110	143	137
13	1500	1200	120	156	120
14	5500	6500	100	130	200
15	4500	4000	50	65	60

Total Unbalanced Bid Price for Estimated Quantities (TUBPEQ).
TUBPEQ = ∑EQ*UP = 4,177,000 LE
UP = Output From the Model

Total Unbalanced Bid Price for Actual Quantities (TUBPAQ).
TUBPAQ = ∑AQ*UP = 4,062,800 LE
UP = Output From the Model

*Population Size = 500,000
*Number of Offspring =5,000
*Maximum Bid Value for Estimated Quantities ≤ 4,177,000 LE
*Model Output Bid Value for Actual Quantities = 4,062,800 LE
*Model Output Bid Value for Estimated Quantities = 4,177,000 LE

Table. 8 The Model Output for Example (3) Try Number Three (Final Optimum).

Bid Items	Estimated Quantity (EQ)	Actual Quantity (AQ)	Direct Cost(LE) (DC)	Balanced Price(LE) (BP)	Unbalanced Price(LE) (UP)
1	3000	3300	10	13	13
2	1200	1500	30	39	60
3	2000	1800	20	26	20
4	3500	3300	50	65	50
5	4000	4500	80	104	160
6	8000	5000	100	130	100
7	9000	9200	20	26	20
8	1000	900	40	52	40
9	500	400	30	39	30
10	800	900	60	78	120
11	6000	5500	50	65	50
12	2500	2700	110	143	110
13	1500	1200	120	156	120
14	5500	6500	100	130	200
15	4500	4000	50	65	50

Total Unbalanced Bid Price for Estimated Quantities (TUBPEQ).
TUBPEQ = ∑EQ*UP = 4,177,000 LE
UP = Output From the Model

Total Unbalanced Bid Price for Actual Quantities (TUBPAQ).
TUBPAO = ∑AO*UP = 4,109,900 LE

*Population Size = 5,000,000
*Number of Offspring =5,000
*Maximum Bid Value for Estimated Quantities ≤ 4,177,000 LE
*Balanced Bid Value for Estimated Quantities = 4,178,200 LE
*Balanced Bid Value for Actual Quantities = 3,888,300 LE
*Model Output Bid Value for Actual Quantities = 4,109,900 LE
*Model Output Bid Value for Estimated Quantities = 4,177,000 LE

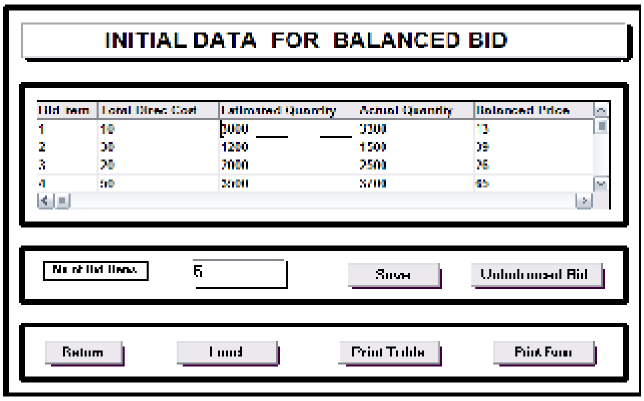

Fig. 1. Screen to Allow User to Enter Initial Project Data for Balanced Bid.

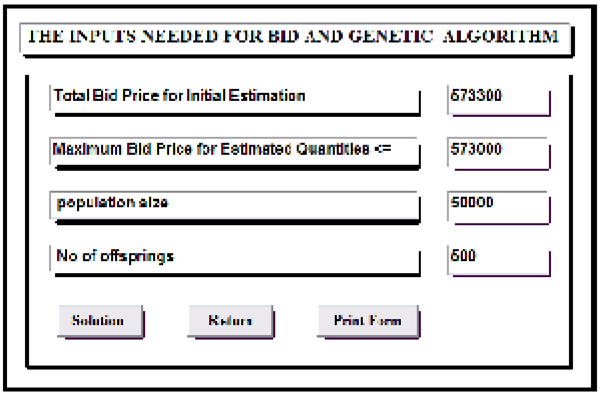

Fig. 2. Screen to Allow User to Enter The Maximum Bid Price for Estimated Quantities and the Input Needed for Genetic Algorithms.

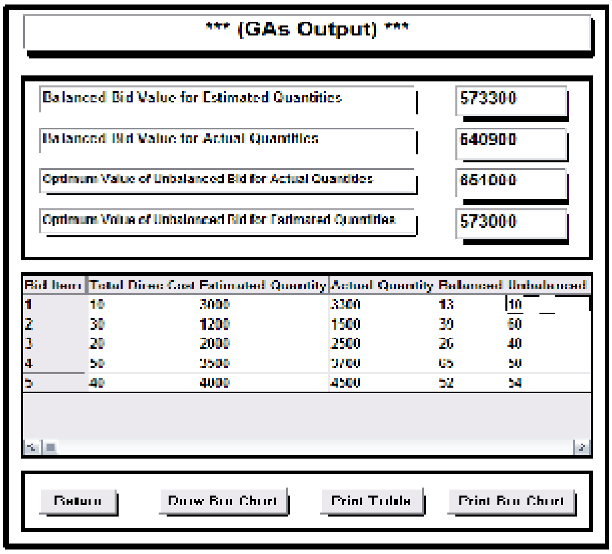

Fig. 3. Screen to Show the Genetic Algorithms Output.

7. Conclusions

Competitive bidding process is essential in bringing success to any general contractor's business. Therefore, any methodology that can be used to improve this bidding performance is of huge value. This paper presents a sophisticated computer program model that aids bidders in preparing competitive bids for unit price contract technique. The proposed model attempts to objectively exploit variation trends in client-provided quantities for the allocation of rates to unit bids for the benefit of the bidder. Moreover, it was devised to determine the unit bids for the unit price proposals with the objective of maximizing the expected profit. Thus, this paper presents a method by which the probability of winning the competitive bidding problem can be improved by obtaining additional information concerning an actual bid items. Using the present model in an unbalanced bid situation, the model not only produces an optimum markup value but also provides the decision-maker with some indication about the implications of win or lose possibility.

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