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A Simulation Model for Bid Price Decision Making

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***Abstract*—**In Lebanon, public construction projects are awarded to the contractor submitting the lowest bid price based on a competitive bidding process. The contractor has to make a strategic decision in choosing the appropriate bid price that will offer a satisfactory profit with a greater probability to win. A simulation model for bid price decision making based on the lowest bid price evaluation is developed. The model, built using Crystal Ball decision-engineering software, considers two main factors affecting the bidding process: the number of qualified bidders and the size of the project. The validity of the model is tested on twelve separate projects. The study also shows how to use the model to conduct risk analysis and help any specific contractor to decide on his bid price with associated certainty level in a scientific method.

***Keywords*—**Bid price, Competition, Decision making, Simulation.

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I. Introduction

IN today highly competitive construction environment, one of the most important decisions that have to be made by any contractor, competing in the market, is which price to bid for when a serious invitation has been received [1]. However, this strategic decision requires simultaneous assessment of large number of external and internal factors. The behavior of contractors as a group (market conditions, number and identity of competitors), individual contractor behavior (contractor size, work and tenders in hand, availability of staff), and behavior toward the characteristics of the contract (type and size of construction work, bid related factors) are the main factors influencing the contractor's bidding behavior [2].

Since it is not usually an easy job to describe the bidding process by a realistic mathematical model interrelating all the above influencing factors, a simulation model for bid price decision making based on the evaluation of the lowest bid price at a pre-contract stage is developed. The model considers two main factors influencing bidding behavior: the project size expressed by the average bid price and the level of competition presented by the number of qualified participating bidders. However, in order to reduce extraneous factors that may distort the study results, all the selected projects constituting the data sample are of the same type (in the field of road construction and rehabilitation projects), awarded according to the same Lebanese formal bidding procedures,

and executed in the same Lebanese market conditions.

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II. Tendering Practices in Lebanon

Competitive bidding is required by law on all public construction projects in Lebanon and the Council for Development and Construction (CDR) is the only public council in Lebanon involved in monitoring, tendering and implementing priority reconstruction and development projects [4]. The usual format of the bidding process is that competitive bidders are invited to submit a bid price for a specified piece of work. Bids are evaluated on the basis of both technical and economical elements and the qualified contractor submitting the lowest bid is awarded the contract [5]. Accordingly, qualified bidders as used in this context are bidders meeting the technical and price consideration criteria for qualification.

III. Method of Analysis

The research procedure is categorized into four phases:
-The first phase reports a statistical description of the selected data sample.
-The second phase invest today highly competitive construction environment, of the most important decisions that have to investigates the correlation between the lowest bid price, the average bid price, and the number of qualified bidders.
-The third phase consists of building the model, conducting simulation runs to evaluate the lowest bid price, and checking the validity of the model.
-The fourth phase consists of conducting risk analysis to help the contractor decide on his bid price with associated certainty levels.

A. Phase1: Data Collection

The data for the study were collected from the archived records of CDR. All projects selected for inclusion in the study were in the field of road construction and rehabilitation in Lebanon. They were publicly bid under a relatively uniform and formal bidding procedure according to the Lebanese tendering law. The data collected from a sample of forty-one awarded projects focused on the value of the lowest bid price for each awarded contract. It also included the number of qualified bidders participating in the bid process and their corresponding bidding prices covering a time period for the years (1996-2006). Among these forty one awarded projects, twenty three are completely executed, nine are still in progress, and nine are not executed. These forty one awarded projects comprised 275 bidding attempts.

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B. Phase2: Regression Analysis

The relationship between the lowest bid price and the number of qualified bidders is investigated.

In this connection, [6] evaluated public projects using the pre-bid estimate (owner's cost estimate) as a reference to determine the deviation of the lowest bid. However, in this study, the average bid price of the bid offers is viewed as a measure of what the group of bidding contractors believes to be the fair value of the work, or what the bidding group views as the "right price." Rather than using the theoretical "pre-bid estimate", the actual average bid price is used as a baseline for the analysis [6].

The relationship between the lowest bid price and the number of qualified bidders participating in the bid process was observed by plotting the value of the ratio of the lowest to the average bid price against the number of qualified bidders. Fig. 1 shows a scatter plot between the two variables of interest.

Using Excel, a statistically significant linear correlation between the two variables of interest is shown. The corresponding linear best fit equation is given by:

$$\frac{Lbp}{Abp} = -0.015N + 0.968 \quad (1)$$

Where, *Lbp*: Lowest bid price,
Abp: Average bid price and,
N: Number of qualified bidders

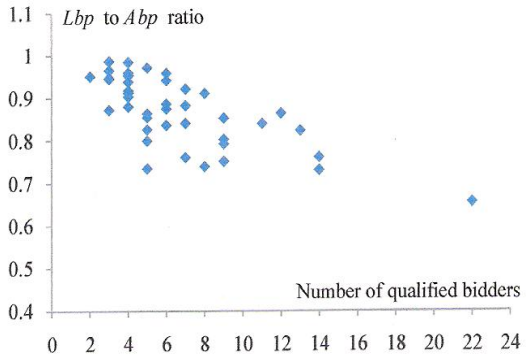


Fig. 1 Scatter plot of *Lbp* to *Abp* ratio against the number of qualified bidders

The correlation is negative, with a linear coefficient of correlation R of -0.714. This shows that as the number of qualified bidders increases, the lowest bid price decreases. The linear relationship also indicates a decrease by 1.5% in the lowest bid price to the average bid price ratio for each additional participating bidder.

This developed linear regression relationship will be used in building the proposed stochastic-simulation model.

C. Phase3: Stochastic-Simulation Model

1. Contractor Capability Index

When a new opportunity is offered, any contractor willing to participate will have his own capability in deciding on which price to bid. This capability is based on the contractor's expertise, size, work and tenders in hand, and availability of staff and equipment. It differs from that of his competitors working in the market. The contractor's capability is defined here by the Contractor Capability Index (*CCI*) which is the ratio of the contractor's bid price to the average bid price of all participating bidders in any specific bid offer.

Thus,

$$CCI = \frac{Cbp}{Abp} \quad (2)$$

Where, *CCI*: Contractor Capability Index and,
Cbp: Contractor bid price

The capability index for any contractor can take values greater than one or less than one. Values greater than one indicate that there are competitors who are able to achieve a bid lower than the contractor's bid price and vice versa.

For any specific contractor, the probability distribution of the CCI is determined by historical records of previous bids that he had participated in.

2. Model Formulation

The conceptual framework of the model developed in this study is shown in Fig. 2.

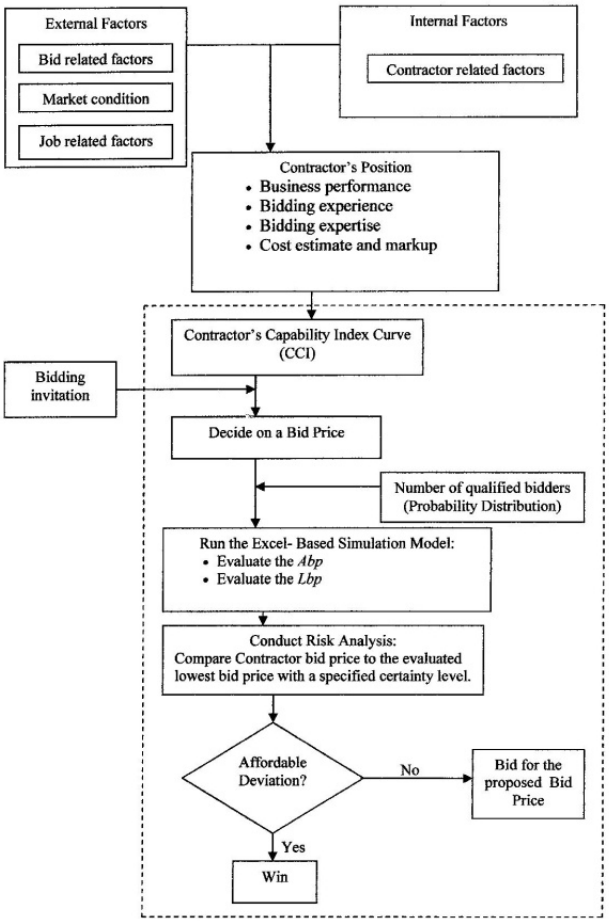


Fig. 2 The conceptual framework of the proposed model

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The developed model aims to help the contractor decide on his bid price with associated certainty level based on the evaluation of the lowest bid price at a pre-contract stage.

The model is built using Crystal Ball decision-engineering software. Fig. 3 describes the procedure of simulation with Crystal Ball.

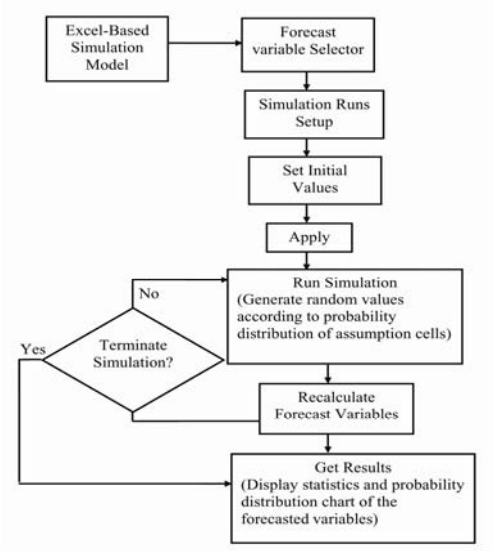


Fig. 3 The procedure of simulation with crystal ball

Using Crystal Ball, three types of variables are defined:

-The assumption variables: variables which values are unsure and uncertain (the number of qualified bidders, *N* and the contractor capability index, *CCI*)

-The decision variables: variables which values are within our control (the contractor bid price, *Cbp*)

-The forecast variables: variables which are unknown (*Abp*, *Lbp*).

Since each contractor in the construction field has his own strategy for bid price decision-making that differs from that of his competitors, the methodology used to evaluate the above mentioned variables necessitates the selection of a specific contractor having a historical experience in the field of road construction and rehabilitation projects. A specific contractor having the greater bidding participation in the data sample is selected. Seventeen out of the forty-one awarded projects used in the regression analysis part included the bidding participation of the selected contractor.

From these historical records, it can be noticed that the contractor has a good capability index in the execution of the proposed works since 65% of his submitted bid prices are below the average bid price.

3. Evaluation of the Abp and Lbp

In order to evaluate the *Abp* and *Lbp* (forecast variables) using Crystal Ball simulation procedure, two assumption variables are defined: the number of qualified competitors and the *CCI*. Due to uncertainty about their values, both variables are defined with probability distributions.

The number of qualified bidders participating in the bidding process varies from project to project. According to the historical records in the 41 collected projects, it is noticed that this number varies from 2 to 22 with 20% highest participation of 4 bidders. Using Crystal Ball distribution gallery, the discrete probability distribution for the number of bidders is constructed.

Using the historical records of the available seventeen participations, the *CCI* probability distribution curve of he selected contractor and the maximum extreme distribution with a mode of 0.88 are constructed. Crystal Ball distribution gallery was implemented to best fit data records of *CCI* using Chi-square ranking method.

Fig. 4 illustrates the evaluation procedure of the *Abp* and *Lbp* using the developed regression relationship and simulation runs.

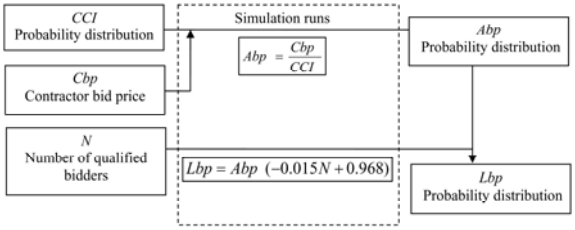


Fig. 4 The simulation procedure to evaluate the *Abp* and *Lbp*

Once an opportunity is presented, the selected contractor can decide on his bid price in a usual systematic method. Deciding on his bid price and using his *CCI* probability distribution curve, the contractor can then evaluate the average bid price for the proposed project using Crystal Ball simulation approach. The average bid price is evaluated using (2). After determining the probability distribution chart of the *Abp*, the evaluated *Abp* and the number of qualified bidders are simulated using (1) to evaluate the *Lbp*

4. Model Validity: Sample Application

To verify the validity of the developed model, twelve separate bidding projects in the specified field are randomly selected. The selected projects are neither included in the regression analysis nor in the determination of the capability index of the selected contractor. These projects are of different sizes ranging from small to more complex. The selected contractor has participated in the bidding process of these selected projects. For each selected project, the number of qualified bidders, the average bid price, the actual lowest bid price, and the contractor bid price are available.

For each project, 2000 simulation runs are conducted to evaluate *Abp* and *Lbp*. Table I shows the contractor bid price, the actual lowest bid price, and the evaluated lowest bid price in the twelve selected projects. In addition, the deviation percentage between the actual and evaluated values of the lowest bid price is also illustrated.

Referring to Table I, results show that the mean deviation of the evaluated mean lowest bid price from the actual lowest bid price for the twelve tested projects is only 2.6 %. Small deviations from actual data records reflect the validity of the developed model. Under similar input conditions, the model is able to reproduce past performance and provide a reasonable

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evaluation of the *Lbp* for any presented bidding opportunity under the specified field of study.

TABLE I
ACTUAL AND EVALUATED *LBP* IN THE TWELVE TESTED PROJECTS

Project	Contractor bid price	Lowest bid price (*Lbp*)		
		Actual	*Evaluated*	%Deviation
1	10,614,642.5	10,151,000.00	*9,818,217.27*	*3.28*
2	5,142,476.18	4,709,672.00	*4,743,128.93*	*-0.71*
3	3,769,733.25	3,620,574.08	*3,482,939.83*	*3.80*
4	3,160,181.00	2,727,063.56	*2,875,464.43*	*-5.44*
5	3,196,793.32	2,781,873.50	*2,853,106.95*	*-2.56*
6	9,116,041.5	8,397,855.00	*8,306,394.69*	*1.09*
7	7,250,000.00	6,355,792.24	*6,619,254.52*	*-4.15*
8	11,792,211.6	11,050,609.45	*10,888,587.46*	*1.47*
9	7,832,365.10	7,382,262.13	7,241,999.15	*1.90*
10	14,019,664.44	11,780,030.00	*12,054,136.49*	*-2.33*
11	2,310,507.00	1,982,718.15	*1,978,356.17*	*0.22*
12	10,132,795.57	8,968,451.72	*9,354,095.14*	*-4.30*
		Absolute mean deviation		**2.6%**
		Sample standard deviation		**1.61**

Also, a 95% confidence interval shows that the absolute mean deviation between the evaluated and the actual *Lbp* is between 1.577% and 3.622%.

D.Phase4: Risk Analysis and Decision Making Scenarios

A main question facing any contractor participating in a competitive bidding process is what decision to take concerning his bid price. Two different scenarios are discussed on project1. The same analysis can be conducted on any other project.

1. Scenario 1: No Change in The Contractor's Bid Price

This scenario considers that the selected contractor can't afford any decrease in his profit margin. So, the contractor's decision is to bid at the proposed bid price as calculated by his responsible staff and wait for circumstances. The contractor will bid for a price of $10,614,642.5. Accordingly, he is certain 80.5% and 30.5% that his price is above the minimum and mean evaluated *Lbp*, respectively.

2. Scenario 2: Change in The Contractor's Bid Price –Case of Interest

Under this scenario, the contractor can afford a decrease in his bid price on the merit of his profit in order to win the project.

If the contractor bids at his proposed bid price of $10,614,642.5, he will take a risk of 30.5% to loose the offer.

If the contractor can afford a decrease of 5% in his proposed bid price and bids for $10,083,910.38, his risk to loose the project will be only 9.58%.

If the contractor can afford a decrease of 8.1% in his proposed bid price, he will be 100% certain that his new bid price is equal the evaluated mean *Lbp*.

If the contractor can afford a decrease of 10% in his proposed bid price, his new bid price of $9, 553,178.25 will be below the evaluated mean *Lbp* with a certainty level of 12%.

Fig. 5 illustrates the four discussed cases.



Fig. 5 Graphical representation of the contractor's bid price decision

IV. CONCLUSION

Future research could be undertaken in developing and refining this model as follows:

-Using a wider range of data that permits increasing the usefulness of the developed regression relationship.

-Updating data records continually.

-Using different contract size groupings i.e. classifying projects according to their monetary size and for each size determining the corresponding regression relationships.

-Determining the contractor capability index for each classification. This will reflect in which project size the considered contractor is more competitive.

-Developing similar models for any construction engineering field and for any specific contractor interested in submitting his bid price based on a scientific methodology rather than only on intuition and experience.

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