USING SIMULATION TO INVESTIGATE FACTORS IN COMPETITIVE BIDDING

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ABSTRACT

The following study was made to measure the effects that certain bidding environmental variables have on long-run expected profits when measured over a simulated time period. The four variables of interest were: 1) tactic used; 2) number of competitors; 3)stability of competitors; and 4) average level of competitors' bids. A four-way ANOVA test was used to reveal the levels of variables and combinations of variables that are significant. Simulation was used as a tool for observing the dynamic behavior of bidding's complex interactive system.

INTRODUCTION

In our society there are usually two or more firms which can provide the service or product requested by a buyer. The buyer is generally interested in receiving the best quality and service for the lowest possible price. Therefore, he/she may advertise their desires and invite bids from any interested firms.

Competitive bidding must be done under conditions of risk, yet, as in most such circumstances, the degree is modified as information is acquired. Knowledge of the variables pressuring the bidding outcome can give a manager a competitive edge. The purpose of this research is to differentiate among those variables in terms of their effect on the long-run objective of maximizing expected accumulated net income.

Bidding Objectives

In nearly all existing decision-theoretic competitive bidding models, the assumption is made that the company's sole objective is to maximize total expected profit. This is probably due to the fact that (1) it is the most common objective and (2) it is the simplest to handle. As far as this author can determine, an evaluation of the performance of these models in situations involving different assumed objectives over a time span has never been done. Also, it might be noted, there is no general model to cover all competitive bidding situations in the literature, so one must resort to the existing expected profit maximizing models.

In this paper an attempt will be made to measure the effects that certain bidding environmental variables have on long-run expected profits when measured over a simulated time period. The experimental instrument developed to do this is dynamic decision-theoretic in nature and takes the form of a computer-based simulation. Profit making performances against uninterested, third-party, computer-generated competitors will be recorded and statistically compared against one another by utilizing the mathematical technique of analysis of variance.

The Bidding Problem

The study of competitive bidding has presented many specific strategies for the bid maker to use to determine his/her bid with the objective in mind of maximizing return. Quantitative techniques, both

deterministic and probabilistic, have been developed to reduce the uncertainty facing the decision maker when submitting the offer of money or services for certain rights or opportunities. These techniques have taken several directions. There are those who have attacked the problem through extensive historical analyses of competitors' actions under similar circumstances (e.g. Friedman (4), Gates (5)). Others have used strategies based upon game theory (e.g. Ackoff and Sasieni (1), Griesmer (7)), Bayesian analysis (e.g. Green (6), Lavelle(8)), and mathematical programming (e.g. Stanley, Honig, and Gainen (9), Stark (10)). Still others claim that success in bidding is largely an art that is developed with experience and knowledge of the many variables unique to each bidding situation (e.g. Bell (2), Edelman (3)).

With these strategies there is created a brand new set of unresolved problems. The bid maker must now make a choice. With very limited knowledge of what the model assumptions are or how they match the firm, he/she must choose that one best matched to the firm and at the same time does the best job of meeting the objective or weighted objectives. The choice is further complicated by the fact that most available models have assumption sets that are nearly the same since they are usually special cases of more general models.

Each of these current methods have merit under certain situations and the selection of which one to use is a major decision problem in and of itself.

In order to effectively use the competitive bidding models that have been suggested for the firm, this paper will attempt to answer the question: When a manager formulates a bid, he should be cognizant of what environmental factors and/or combinations of factors? It will suffice to ascertain that a chosen bidding strategy can benefit a company with costs to be weighed against benefits in each special instance to decide whether the procedures to effect the strategy will in fact be used.

When n firm has either made the decision to pursue a more rational procedure in the formulation of its future bids or it has recently changed its objectives necessitating a change in bidding strategy, it still needs the answers to the following questions:

a) What are the criteria used to judge one strategy against another? A common denominator or several common denominators must be used at least to arrive at an ordinal measure of ranking.

b) Of the strategies available, which one best fulfills the objective set for the firm? The common denominators used above should be developed so as to be consistent with the objectives of the firm. Short run objectives often modify the importance of criteria and this changes the ranking of possible strategies.

c) Is the strategy/objective match feasible with the amount of information and resources

available? The optimum solution is sometimes infeasible because of timing, manpower available, or other uncontrollable variables. In the future, given more resources and data, a re-evaluation would determine the usefulness of the optimum match.

d)   And finally, will the strategy/objective match benefit the firm with costs weighed against benefits in each special instance? In all cases the developer of an existing bidding decision model warns of its indiscriminate use. Important benefits may come from the use of a rational model but not necessarily from any particular one.

THE RESEARCH

Research Setting

The scope of this paper will be limited to the following bidding procedure example. Consider a bid submitted by a contractor as the money tradeoff for which the contractor would provide service in return. This price includes the best estimate of direct cost, overhead, profit, and an amount for contingencies. His service is usually completely described in a specification list provided by the bid lettor in the call for bids. When bidding, the competitors for each job are known to each other but all bids are sealed. At a specified time after all bids are in, bids are opened, the award is made to the lowest bidder, and information concerning the identity of all bidders and their total bid amount is made public. There is no information, however, on how each particular competitor has separated his total bid amount among costs, profit, and contingencies. The lettors in all cases will give their engineering estimates of the costs of the projects and these will be included in the specifications of the jobs. The above description will be called an "all-bidders-known" bidding situation.

Research Variables and Hypotheses

By the very nature of the bidding process, a contractor must function under conditions of great risk. However, this risk can be reduced by drawing upon the decision scientists' tool of expected value. The margin of error can be made smaller by a systematic study of the environmental variables surrounding each bidding situation. Of the many variables present in an all-bidders-known bidding situation, four were chosen to be investigated in this paper because of their high possibility of control by the contractor. These include the statistical tactic employed to arrive at an "optimum" bid. the number of competitors' bids on each separate job, the standard deviation of the competitors' bidding markup distributions, and finally, the arithmetic mean of those distributions. The research hypothesis is stated thus: There are variables present in an all- bidders-known bidding situation that individually and in combinations have a significant effect on its outcome.

The accumulated long-run profit as a consequence of the use of each of two statistical tactics was examined in detail. One tactic was that suggested by Friedman (4) and the other, the tactic suggested by Gates (5). The choice of which tactic to use is completely under a contractor's control, assuming he has the information necessary for application.

If this research shows a large number of competitors in a bidding situation to be a portentous factor, then, if possible, a contractor might try to avoid those particular bids.

Time and money are needed for the record keeping necessary to determine the historical bidding markup distributions for each competitor. If their means and standard deviations are not significant, then resources may be saved by ignoring them. Otherwise, neglecting them may be false economy.

Experimental Model and Procedure

A computer-based simulation model was used to determine the levels of accumulated long-run profit a firm might expect to accomplish when operating under combinations of the levels of the experimental factors. Other ways are possible to accomplish the same results, however not with the same degree of feasibility. It is too costly to actually experiment with the resources of a contractor's firm. Simulation is quite often the best way to observe the dynamic behavior of complex interactive systems.

Basically, the referent system of the simulation is similar to the example given above. Jobs are generated by the computer for bid by both the experimental, computer-controlled contractor and by a varying number of computer-controlled competitors. Levels of the research parameters are controlled by lead cards in the data for each simulated run. Two tactics, three levels of number of competitors, three levels of means, and three levels of standard deviations are used in all combinations making it necessary to have fifty-four runs. Each run simulates fifteen months of operation and includes bids of over 100 jobs apiece. By controlling the random number sequence used for each run, the same jobs were made available for each combination of the research variables. The experimental unit observed as a measure of performance is the accumulated profit gained over the fifteen month span of operations.

A four-factor analysis of variance (ANOVA) was used to test the statistical significance of the effects that the factors have upon long-run profits. Consideration was made of the effects of all the factors taken singularly and in combinations.

LEVELS OF RESEARCH VARIABLES EXPLAINED

Tactics

After several semesters of playing a bidding strategy game developed by the author, students noticed differences in times and conditions of when one tactic appeared to be superior to another. There were situations where the tactic supported by Gates performed better than that supported by Friedman, times when the reverse was true, and other times when there seemed to be no discernable difference in either's performance on long-range equity gain.

The probability of being low bidder on any given job and, consequently, the profits to be obtained from that job, depend both upon the bidding characteristics of the individual competitors and the means of combining these characteristics into one effective set of winning probabilities. Although different contractors exhibit different bidding characteristics, their combined effect on a contractor's chances of getting the job can be computed. The method to do this is in dispute at

this writing. The tactics used by Friedman and Gates are mathematically antithetical and thus were the two that were compared experimentally.

Let w~ be the event of winning at a markup of aC measured as a percent of estimated cost. Let w~ ,
    w⁶,…..wº be the events of beating competitors numbered 1,2,3   n with a markup of o(. Friedman's basic model,

$$f(\alpha) = P(W_\alpha^\bullet) = \prod_{i=1}^{n} P(W_\alpha^i)$$

assuming statistical independence and no collusion among the competitors, gives:
eq. (1)
as the effective probability of winning with a bid using a

$$eq. (2) \quad f(\alpha) = P(W_\alpha^\bullet) = \frac{1}{\frac{1-P(W_\alpha^1)}{P(W_\alpha^1)} + \frac{1-P(W_\alpha^2)}{P(W_\alpha^2)} + \cdots + \frac{1-P(W_\alpha^n)}{P(W_\alpha^n)} + 1}$$

$$eq. (3) \quad = \frac{1}{\frac{1}{P(W_\alpha^1)} + \frac{1}{P(W_\alpha^2)} + \cdots + \frac{1}{P(W_\alpha^n)} - (n-1)}$$

markup of o~. against n known competitors.

If one assumes statistical dependence:

The second algebraically equivalent form is given since it is easier to manipulate, especially with a table of reciprocals available.

Equation #1 was used to represent Friedman's proposal as the appropriate tactic (Tactic I) and equation #3 was used to represent Gates' proposal as the appropriate tactic (Tactic II).

The Number of Competitors

For experimental purposes in this research the number of competitors is controlled and used as a factor in the factorial design. Three levels of this factor are selected to represent low, medium, and high. These are two, four, and six competitors, respectively. Since it is desired to generalize the results due to this factor, it is treated as a random effects variable.

The Variability of a Competitor's Bid Markup

Consider two competitors who have identical average bid markups when viewed over their past bidding history. Competitor number one might be referred to as being very stable in bidding, determined by reasoning that the variance of their distribution of historic markups is very small.
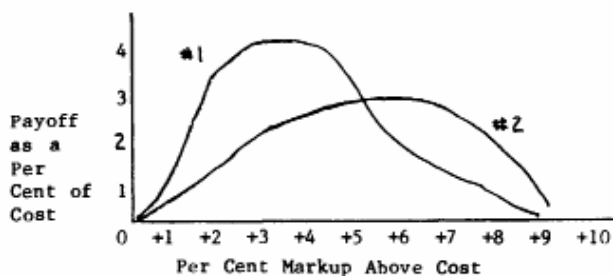
Competitor number two, however, has been quite erratic in the determination of markups and this is made apparent by a much larger variance.

Figure 1 extends this situation to a payoff chart by taking each markup and multiplying by the probability of winning at that markup. It is seen that one can expect to fair better against a steady competitor than against an erratic one. The present study is designed to test the significance of this observation and to note its interactive effect with the other variables.

Three levels of standard deviations are used in this research. Markup standard deviations of two, eight, and fourteen per cent above costs are taken to represent a low, medium, and high value. This variable is also considered to be a random-effects factor in the design.
The Mean of a Competitor's Bid Markups

Consider another pair of competitors with identical dimensions of stability measured by their variance as was done in the last section. In this case, competitor number one has a tendency to bid at a higher markup level than competitor number two.

A priori, when taken alone, a rise in the mean bid level of a competitor will result in a higher expected payoff for the manager. How this is tempered when other bidding variables are introduced will be investigated.

As with the standard deviation and number of competitors, the mean is assumed to be of random-effects and three levels: eight, sixteen, and twenty-five, are used.

RESULTS OF SIMULATION RUNS

The "optimum" winning markup percentages are given in Table 1. These were determined in each run by the computer when following the formula dictated by the particular tactic considered (eq. #1 and eq. #3). This "optimum" markup was used for all bid formulations in any given cell. The computer- generated competitors followed a distribution with parameters as given by the left-hand columns of the table.

Table 2 presents the results of the fifty-four simulated runs

FIGURE 1.--PAYOFF CURVES WHEN BIDDING AGAINST TWO COMPETITORS WITH EQUAL MEANS AND UNEQUAL VARIANCES

TABLE 1
"OPTIMUM" MARKUP PERCENTAGES USED IN SIMULATED RUNS
(Percentages of Estimated Cost)

St. Dev.	Mean	Tactic I No. of Competitors 2	4	6	Tactic II No. of Competitors 2	4	6
2	108	5.4	4.7	4.3	5.4	4.8	4.5
	116	12.4	11.8	11.4	12.4	11.8	11.5
	125	20.9	20.3	20.0	20.9	20.3	20.0
8	108	6.1	4.0	3.0	7.7	6.4	6.1
	116	9.9	7.2	6.1	11.0	9.0	8.0
	125	16.0	13.1	11.9	16.2	14.0	13.0
14	108	8.5	5.2	3.8	11.6	10.4	9.9
	116	11.5	9.1	5.9	14.1	12.0	11.2
	125	16.1	11.6	9.3	17.9	14.4	13.0

in terms of resulting over-all equity gain. Each run was allowed to continue for fifteen periods (months) with eight jobs made available per simulated period. Limiting bonding capacity often kept the test contractor from submitting a bid for all eight jobs, however in each case more than one hundred bids were offered.

TABLE 2

RESULTS IN EQUITY GAIN AFTER A SIMULATED FIFTEEN MONTHS OF OPERATIONS

Standard Deviation	Mean	Tactic					
		I			II		
		Number of Competitors			Number of Competitors		
		2	4	6	2	4	6
2	108	$ 2,081,533	2,245,895	2,337,718	2,081,533	2,318,814	2,390,610
	116	6,253,466	6,689,974	6,118,943	6,253,466	6,689,974	6,176,366
	125	11,328,486	11,356,626	11,114,504	11,328,486	11,356,626	11,114,504
8	108	1,316,059	238,548	90,613	1,522,353	141,827	-290,324
	116	3,844,485	2,817,498	1,887,365	3,816,127	1,693,805	1,509,970
	125	6,870,586	5,757,143	5,968,295	6,963,816	6,075,507	5,702,315
14	108	1,735,914	60,051	-182,646	1,850,713	-205,135	-292,425
	116	3,217,837	797,671	461,432	3,037,997	660,166	178,902
	125	5,734,027	2,378,716	2,990,760	6,098,996	2,568,009	1,417,302

General Implica

This research has shown that most bidding problems are generated by the entry into the competition of the contractor who is very unpredictable in his actions. The unpredictability is usually caused by seemingly irrational bid formulations of a known competitor rather than by the unfamiliarity of an unknown, new entrant. With these finding, together with the review of previous writings on the subject of competitive construction contract bidding, one bit of advice to the practitioner stands out above all the rest. Definite competitive advantage is gained by the use of rational quantitative techniques involving any information available about previous competitors' performances. The conclusions reached in this research can take the contractor several steps further. To improve the end results, a strategy must include a measure of variables inherent in any bidding situation, Of particular interest in this study was the effects that combinations of various levels of competitor numbers, average markup, and competitor stability had on expected accumulated profit performance.

Specific Findings

Statistical Tactic Used.

No statistically significant difference between the two tactics occurred in the experiment. This was true when the tactics were considered alone and in combination with the other research variables. Since Tactic II proposed by Gates dictates a higher bid level than Tactic I proposed by Friedman with approximately the same long-term equity gain, the logical conclusion is that Tactic II will allow one to reach the same level of accumulated profits with a fewer number of completed projects. What happens at the extreme cannot as easily be deduced. If the bidding environment consists of a large number of competitors with a high

measure of fluctuations in their markup history, then the difference between the two "optimum" markups will be at the greatest level.

The poorer performance of the Gates' tactic under these conditions is important to note even though the results over all levels of the variables considered were not statistically significant.

Number of Competitors.

Increasing the number of bidders does lower the "optimum~ winning bid irregardless of whether Tactic I or Tactic II is used. As the number of bidding competitors increases, the "optimum" bid level decreases at a faster rate when applying Tactic I. Contrary to many authors it was found that, when considered alone over the average levels of all the other experimental variables, an increase in the number of bidding competitors does not necessarily adversely affect accumulated profits. A substantial recovery of any loss in expected profit due to the lowered winning bid is made by lowering one's bidding markup by a wider margin, thus increasing the probability of winning which results in the capture of a larger percentage of jobs. The amount of the margin of decrease was found to be much less when the bidding markups of competitors was relatively stable.

Stability of Competitors' Bidding Performance.

The sacrifice that must be made above when bidding against an increasing number of competitors is often not one of expected profits but the necessity of doing more work. The amount of additional work is a function of the reliability one has on the actions of the competitors and of the bidding tactic employed. If a contractor is so unfortunate as to find himself in a position of bidding in an environment consisting of a large number of highly erratic bidders whose mean bid markups are low, then no amount of additional work will help. Such a situation is fatalistic for all participants. At the other end of the spectrum, the most desirable bidding environment consists of competitors who bid rather consistently at a high level. Wide changes in numbers of bidders have almost no ill effects while the tactic one uses in this situation is irrelevant.

Average Level of Competitors'. Bids.

This research strengthens the belief that one performs better, profit-wise, against competitors who have a history of high average bid markups. The hypothesis of no differences had to be rejected. The research shows that significant interaction effects exist between the levels of means and standard deviation. The contractor should, because of this, consider these variables as pairs. However, by the careful examination of Table 2, the cause of the non-additive relationship seems to occur when the number of Competitors is low. Individual variable considerations should be made at other levels of number of competitors.

The investigations made in this paper show that various combinations of the four research variables produced widely varying results. This makes it clear that the levels of these variables should be considered before a bid level is formulated. Each bidding situation is likely to have other environmental variables that have not been considered in this work. There is no reason to believe that their actions and interactions have less effect on bidding success.

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