Reducing Risk by Leveraging Information for a Competitive Advantage in Bidding

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ABSTRACT

Sales management is responsible for securing business by submitting bids for contracts to supply their products to wholesalers and retailers. In this case study, the bidding information was organized to improve the process for evaluating each contract using a model. The model is used in daily operations to price products in a frequently repeated, sequential auction environment for contracts awarded to the lowest price. This methodology quantifies three factors in developing a probability distribution describing the potential of winning the contract. These factors include the competitor's reaction to the last winning bid, the second lowest bid and their own bid. Other factors that influence the pricing decision, such as quantity, geography, and number of competitors, are included in the selecting of contracts to build the model. For over a decade, management utilized this technique to maintain over $300 million in sales each year.

INTRODUCTION

Competitive bidding is an integral part of many businesses generating substantial revenues. On products that are standard or similar, the primary purchase criterion is price. Within this highly competitive environment, it is common practice in many industries to require all interested firms to submit a sealed bid for a given contract to supply goods or services. This includes many manufacturers and service organizations that are selling to other manufacturers of original equipment, as well as wholesalers, retailers, federal, state, and municipal governments, and others. The contract is awarded to the firm with the lowest bid. The process of developing a bid requires the manager to rely on a high level of quantitative and intuitive skills in determining the price (Rothkopf, 2007). The bidding system is part of a marketing decision support system (MDSS) used by either a sales or marketing group. MDSS was described for a division of General Electric by Lillis and McIvor (1985). Their MDSS bidding system provided an analysis of the data but no model to assess the probability of winning. In most situations, the manager needs a model to assist in responding to all contracts. Therefore, the components of a bidding support system should include a bidding model as depicted in Figure 1.

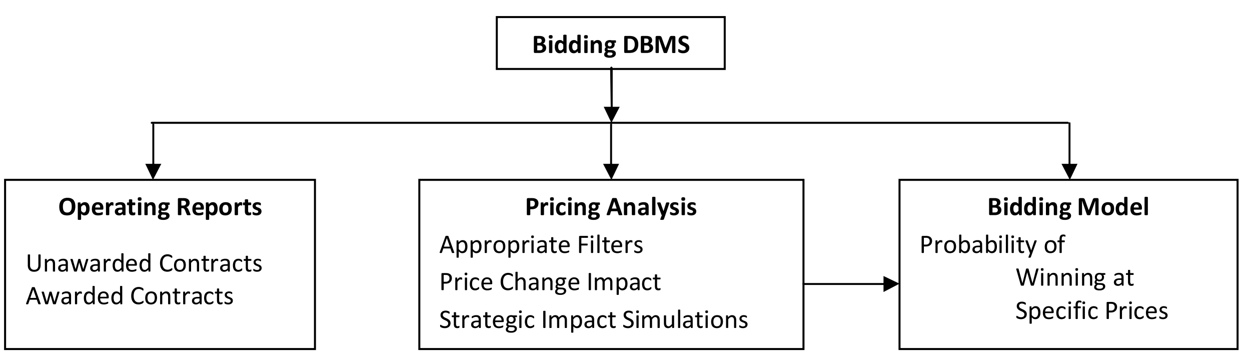


Figure 1: Bidding System Overview.

This case study describes the development of a system for pricing contracts in the pharmaceutical industry. The decision process involves the collection and assembly of the information to be used in a model to assist the manager in evaluating contract bids. The bidding model focuses on that aspect of competitive bidding wherein a manager routinely bids for the right to supply his company's products to another over a specific period of time, usually one year. The contracts involve similar, non patented products that may be identical or interchangeable, permitting the purchaser to buy from anyone of several competing sources. A large customer base creates a high volume of activity, with several bids every day for a product. With a large number of contracts generated for each product, the importance of an individual bid diminishes. Thus, no single contract jeopardizes the survival of the company or has a significant impact on the company's profitability.

Substantial research efforts were devoted to different aspects of the bidding problem. Comprehensive bibliographies on competitive bidding were compiled by Stark and Rothkopf (1979) and Rothkopf and Harstad (1994). Engelbrecht-Wiggans (1980) reviewed the state of the art in his survey on auctions and bidding models. A survey by Laffont (1997) focused on the application of game theory to auction data, and Rothkopf and Park (2001) defined the issues to be resolved in designing an auction. Quantitative approaches to competitive bidding can trace their roots to the research of Friedman (1956), who published the earliest biographical listing. The models proposed by Friedman evaluated an individual contract using expected value. Construction projects (Chen, 2007; Dyer & Kagel, 1996; Elmaghraby, 1990; Skitmore, 2002), federal government contracts (Samuelson, 1986), and oil lease procurement (Keefer et al., 1991) research assesses an individual contract where the bidder carefully evaluates the value of the contract as it relates to the survival of the company or in terms of a substantial impact on the company's profitability (Pfeifer & Schmidt, 1990). Here, the bidder has a long period of time (weeks or months) in which to determine a single bid. More complex single auctions such as withdrawable bid situations (Harstad & Rothkopf, 1995; Rothkopf, 1991) have also been modeled. In contrast to the 'one-shot' situation, this paper deals with a sequence of bids, each prepared in less than an hour and each of which has a small impact on profit.

A sequence of bids to supply products or services presents a more complex situation. Kortanek, Soden and Sodaro (1973) addressed the problem of a sequence of sealed bids for future undifferentiated but interrelated contract work. Each contract utilizes a predetermined amount of several restricted resources at a later time. A linear programming formulation maximizes the profit contribution from winning some or all the contracts in the sequence. Constraints are imposed by the number of units each machine can manufacture. The objective is a linear combination of direct cost, opportunity costs, and a competitive advantage fee. The last two costs are modified based on a simple hierarchy defining four possible levels of difficulty regarding the information that is known when bidding. Similarly, a mixed integer programming model was developed for outsourcing of information systems (Nam, Chaudhury & Rao, 1995). These and other earlier papers assumed that the competition will not react in later bids to what the bidder does on previous bids. Oren and Rothkopf (1975) built a model bidding on sequential contracts in which the competition reacted to earlier bids. The behavioral approach views the dynamics of the trade in a sequential auction as a multistage control process. These models lead to the conclusions that (1) the sequential bid equilibrium is generally different from the one-shot equilibrium, (2) aggressive repetitive bidding influences the competition to be aggressive, resulting in lower prices, and (3) the bidder must indicate that he will react to the competitors' bids. In high volume situations, this strategic bidding decision is simplified by operating managers who specify the minimum market share required to maintain production.

An extensive discussion on the relative usefulness of decision theory and game theory for analyzing decisions in a competitive environment is presented in Kadane and Larkey (1982), Harsanyi (1982), and Rothkopf (1983). These papers focus on the derivation of the subjective probability distributions used to describe the strategies of an irrational competitor. Irrational behavior is attributable to organizational, informational, computational, competitive, emotional, or anticipative factors. The authors agree that an empirically supported psychological theory making probabilistic predictions about future competitors' bids is required. Such a function was proposed by Rothkopf (1983) for a model developed for semi-rational behavior in sequential auctions. In certain cases, a function characterizing future competitive reactions is more important than a complex model integrating potential competitors and other assumptions. The probability distributions of the following model are designed as a function describing future competitive reactions.

The components of the bidding system in Figure 1 are described in the next sections. In Section 2, the bidder's environment is further defined in terms of the historical information required; the operational aspects of acquiring, recording, and reviewing the data for accuracy; and the analysis necessary to understand the market and select the appropriate data for use in the model. The model that develops the probability of winning the next bid at different prices is described in Section 3, while Section 4 gives an illustrative example of the process. A history of the validation of the model is presented in the final section.

BIDDING ENVIRONMENT

On a daily basis, the contract manager is responsible for preparing numerous bids for different products. The complexity of the problem is compounded by the critical factor: time. The bidder must wait until just before the submission deadline in order to consider the latest competitive bid prices in that product category. Quantitative factors along with information from the field force and corporate headquarters are combined with the bidding history to derive the final bid price. Since there is only a short period of time in which to make each decision, management is under constant pressure. Sales administrators submit about thirty contracts per week to over five thousand hospitals, pharmacies and government facilities. Although the company sells twenty products, each product is not sold to all customers. Therefore, the manager is responsible each day for about thirty bids involving up to eight competitors. Price is critical in obtaining each contract. In addition to internally developed bidding DBMS, there are toolkits that provide the basic charts, tables and checklists to assist management in bidding.

The contract manager's initial task (Figure 1**,** Operating Reports) is to maintain a real-time database updated with all the latest bid information. The historical data base includes all bids from as many contracts as possible, whether or not the Firm was a participant in any of them. (In this paper, "Firm" always refers to the company that owns and operates the bidding system, while all other companies are considered the competition.) Initially in the collection process a sample of bids sufficient to identify the basic competitive bidding patterns for each product is acquired. When the system became fully operational, the field force reports on all contracts. Since products on a single contract are not bundled (bid on the total value of all products on the contract), each product is considered as a separate contract. Thus, product and contract are used interchangeably. For each contract, the following basic information is required:

- Description of Product for $Contract_j$
- Customer Information with Submission and Award Dates
- Any Qualitative Information
- Quantity (number of units), Q_j
- Winning Bid Price, WIN_j
- Second Lowest Bid Price, SEC_j
- Firm's Bid Price, $FIRM_j$
- Competitor k's Bid Price for $Contract_j$ $COMP_{k,j}$

Prices submitted for a contract are public information on government awards as well as in many hospitals and pharmacies and are available upon request. Management includes the collection of the necessary information as part of the sales representative's duties for the company, thus producing the data necessary for the bidding model. Management monitors operations using the Unawarded Bid Notices Report and the Awarded Bid Notices Report. The list of unawarded bids contains all the open or outstanding contracts in which the final winner has not yet been identified. The manager uses this information to collect the final results after the award date has passed and to estimate the company's potential commitment to supply a given number of units. Production and inventory control are improved by projecting the number of units that could be sold for this product. The awarded bids report functions as a monitoring device for the entry of information and an overview of the latest bids for all products.

The next task (Figure 1, Analysis) is intended to provide an understanding of the current market conditions and identify those contracts relevant to the next group of bids. The results are used to develop the filtering process to extract the appropriate data from the history files before performing any impact analyses or estimating the probability of winning using the model. After reviewing the Profile Reports, the manager addresses the issue of which contracts to include based on an analysis of the competitors for each product, the impact of quantity on the process, and effect of weighting bids over time.

Profile reports tabulate the variables from the contracts, which include product, sales territory, sales district, sales region, city, state, zip codes, prices, size of contract, competitors, customer type, submission date, award date, awarded company, second lowest bid, and bid price indicating the frequency of occurrences for each value. Prior award dates provide valuable information on seasonal variations and future demand patterns. Reviewing the bid prices by area of the country might indicate that the competition has its regional managers submitting the bids. If this appears true, the remaining analyses are conducted for each geographic area.

The competitors are evaluated next. Heshmat (1996) constructed a model based on the number of bidders and used a "fudge" factor to estimate the impact of multiple bidders, while Landsdowne (1996) determined the optimal number of bidders for the purchaser to achieve the best price. In contrast, this model focuses on specific data and makes a decision on each contract. Thus, if all the competitors statistically exhibit the same distribution of bids, then the groups are combined into a single entity, the competition. However, when more than one style of bidding is clearly demonstrated, the model is applied to each type of bidder, and the lowest price for the percent of market share desired is used to establish the next bid for the Firm. A competitive group may be composed of a single company. If a bidder is known not to participate on a given contract, then the competitors are eliminated from the analysis on that bid.

The quantity is analyzed to determine if the competitive groups bid lower on contracts involving a greater number of units. Again, if a price difference is detected, the bids are extracted for a given range of prices, otherwise all prior bids are used.

Finally, the remaining contracts, relevant to the current bid, are examined to determine if the history of bids or the changes between bids in the factors (described in the next section) are changing over time. A weighting function placing more emphasis on the current data is examined. However, if a clear change in bidding is identified (i.e., the competitor hires a new manager), then only the contracts after the change in pattern are used without weighting. Another set of weights is derived for the three factors in the model. These are discussed in the next section after the factors are defined.

With the contracts filtered for those considered relevant to the current bid, the total impact is evaluated. The price change report is a "what if" analysis evaluating the question, "What would have been the change in profit if we had decreased (or increased) our bids by X percent?" This analysis assumes that the competition would have bid the same prices and not reacted to the Firm's new bid. Even with this assumption, the report gives the manager a measure of how sensitive the market is to a change in price. To achieve a more realistic answer, the probability distributions from the model described in the next section are used in a simulation in which the competitors' and the Firm's bids are modified to react to the changing environment

The final task (Figure 1, Bidding Model) is the implementation of the model and utilizes the results of these analyses. The extraction criteria select the appropriate contracts from which the probability distributions are developed. The desired market share strategy is determined based on the impact evaluation.

BIDDING MODEL

The forecasting methodology applied to the bidding environment employs a dynamic technique that assesses the marketplace and combines historical bidding patterns into a probability distribution describing the competitor's next possible bid. The model formulation reflects the application of behavioral statistics that quantify the probability of a given competitive price by combining three factors related to the competitor's latest bid. This is similar to the learning agents described in Bandyopadhyay, Rees and Barron (2008).

The current state of the marketplace is the first and most important factor. The trend of the contract prices indicates the fair market value of the product over time. The competitor's reaction to the changes in winning bids is reflected in their bidding relative to the prior winning bid. For example, if the competitor lost the last bid, they might react by bidding below or the same price as the last winning bid. If they won the first contract, they might bid the same price again. Thus, the competitor will adjust their next bid after reviewing the prior winning bid.

The second factor concerns the lost profits from the amount that was 'left on the table.' This is equal to the increase in revenue that could have been achieved had the winner only underbid their nearest competitor by $ .01 per unit. The money 'left on the table' concept is applicable only if the competitor won the last bid and management realizes their lost opportunity (Engelbrecht-Wiggans & Katok, 2009, 2008, 2007). In an article on federal offshore leases by Engelbrecht-Wiggans (1989), the bidder's regret addresses "the concern over 'money left on the table' - the amount of money the winner could have saved himself in a first-place sealed-bid auction had he known, when he bid, what his nearest competitor would bid." The author develops a bidder's utility function that is a linear combination of profit and regret. This is an extension of Bell's (1982) work. Although this article involves a single bid auction, it indicates the increased awareness of researchers in the regret from lost revenues that the bidder actually considers. This factor is measured by the difference between the competitor's last bid and the prior second lowest bid only when the competitor won the prior contract.

The third factor represents the corporate strategy that dictates the internal policy guidelines or rules that management imposes on each bid. For example, management may not want to lower the price by more than a given amount or percentage on consecutive bids. This factor is measured by the change in that company's consecutive bids.

The emphasis that the competition places on each of these factors varies from product to product (Lorentziadis, 2010). Thus, a set of weights is developed for the factor assigned to a product. The initial weights, $WEIGHT_i$, are derived from a correlation analysis using the most recent sequence of bids. The three correlations involved are: (1) the difference between the last competitor's bid and the prior winning price; (2) the difference between the competitor's last bid and the prior second lowest bid; and (3) the difference between the competitor's last two bids. The number of historical contracts and the frequency with which the correlation analyses are run depend on the volatility of the market. For volatile markets, fewer contracts are used, with a shorter time between correlations in order to react to the changing market. Stable markets can utilize a longer sequence of bids with less frequent analyses. The correlation analysis determines the initial weights or the extent to which each relationship impacts the competitor's next bid. In a sensitivity analysis, the final weights are derived by varying three factors' weights and applying the different sets of weights to historical data to estimate the next bid. The different sets of projected bids were compared to the actual bids. The weights that produced the minimum sum of differences between the actual and projected are used in the model as the final weights, $FWEIGHTS_i$.

For the following mathematical representation of the model, the contracts are numbered in time sequence. The contract for which the Firm is preparing a bid is n+l, while the previously awarded contracts are sequentially numbered from 1 to n. The number of contracts, n, used in the model varies by product and factor. The nth contract is the most recent contract on which there is information. Three factors are modeled as influencing the competitor's next bid:

Winning Bid Price on the jth Contract	WIN_j
Second Lowest Bid Price on the jth Contract	SEC_j
Competitor k's Bid Price on the jth Contract	$COMP_{k,j}$
Number of Awarded Contract	n

Factor 1 The competitor's reaction to the winning bid is the difference between the winning bid and their next bid for this product.

$$CHANGE_{l,j} = WIN_{j-l} - COMP_{k,j} \qquad \text{for } j=2, \ldots, n \qquad (1)$$

Factor 2 If the competitor won the prior bid, the 'money left on the table' is the difference between the competitor's prior winning bid and the second lowest bid on the prior contract.

$$CHANGE_{2,j} = SEC_{j-1} - COMP_{k,j} \qquad \text{If } COMP_{k,j-l} = WIN_{j-1} \quad \text{for } j=2, \ldots, n \qquad (2)$$

Factor 3 The competitor's pricing stability is measured by the change in the competitor's consecutive bids.

$$CHANGE_{3,j} = COMP_{k,j-1} - COMP_{k,j} \qquad \text{for } j=2, \ldots, n \qquad (3)$$

The final step in the extraction analysis is to derive the weights applied to each Factor in the following process. The impact of each Factor is estimated using the results of three correlation analyses. For Factor 1, the correlation between the competitor's current bid and the prior winning bid is calculated ($CORR_l$). Factor 2's correlation ($CORR_2$) assesses the relationship between the competitor's current bid and the prior second place price provided that the competitor won the prior bid. Similarly, the third Factor's correlation value ($CORR_3$) is based on the competitor's current bid compared to their last bid. These correlation values are used to compute the initial weights for each factor.

$$WEIGHT_i = CORR_i \,/ \sum_{m=1}^{3} CORR_m \qquad \text{for I} = 1, 2, 3 \quad \text{(Factors 1, 2, 3)} \qquad (4)$$

The final weighs, $FWEIGHT_i$, are derived from applying the correlation weights, $WEIGHT_i$, to the historical analyses where the weights are varied to predict the most accurate value for the next bid. The methodology for projecting the competitor's next bid is given as follows:

Step 1 Compute the probability for each incremental value of CHANGE for each factor.

$$PROB(CHANGE_{i,j}) = 1 / n-1 \qquad \text{for } i=1, 3 \text{ (Factors 1 and 3) and } j=1, \ldots, n$$

$$PROB(CHANGE_{2,j}) = 0 \qquad \text{If } CHANGE_{2,j} = 0\text{, otherwise} \tag{5}$$

$$= 1 / (n-1-d) \qquad \text{for } j= 1, 2, \ldots, n \text{ (Factor 2 Only)}$$

Where d = Number of times the competitor won the bid with no 'money left on the table' or $CHANGE_{2,j}$ =0.

Step 2 Calculate the weighted probability of each change for each factor.

$$WTPROB(CHANGE_{i,j}) = FWEIGHT_i \times PROB(CHANGE_{i,j}) \tag{6}$$

For i= 1, 2, 3 (Factors 1, 2, 3)
j = 1, 2, ... , k(i)

Note: $FWEIGHT_i$ is the weight assigned to each FACTOR.

$$\sum_{i=1}^{3} FWEIGHT_i = 1.00$$

Step 3 Establish the new bid prices by adjusting the CHANGE value relative to the latest value for that factor. This applies the changes in the bid pattern to the current situation.

$$\begin{aligned} ADJPRICE_{1,j} &= WIN_n + CHANGE_{1,j} && \text{for } j = 1,2, \ldots, n \\ ADJPRICE_{2,j} &= SEC_n + CHANGE_{2,j} && \text{for } j = 1,2, \ldots, n \\ ADJPRICE_{3,j} &= COMP_n + CHANGE_{3j} && \text{for } j = 1,2, \ldots, n \end{aligned} \tag{7}$$

Step 4 Sum the probabilities for each adjusted bid price. BID_m is a set of adjusted prices with the duplicates removed.

$$BID_m = ADJPRICE_{i,j} \qquad \text{If } ADJPRICE_{i,j} \neq BID_q \text{ for } q = 1, \ldots, m \text{ for } m=1, 2, \ldots;\ i=1, 2, 3;\ j=1, 2, \ldots, n$$

$$PROB(BID_m) = \sum_{i=1}^{3} \sum_{j=1}^{n} WTPROB(CHANGE_{i,j}) \text{ If } BID_m = ADJPRICE_{i,j} \text{ for } m = 1, 2, \ldots \tag{8}$$

Step 5 The probability of winning the next bid at a given price is the cumulative sum of probabilities for all bid prices above a specified value for the Firm.

$$PROB(WINNING) = \sum_{BID_m > \text{FIRM'S BID VALUE}} PROB(Bid_m) \tag{9}$$

This process allows the manager to derive the best response for the strategies used by the competition.

Management uses the strategy which, for the strategies employed by the competitors, achieves the market share desired.

ILLUSTRATIVE APPLICATION

The model is illustrated using actual bids submitted to the federal government for a product that is periodically replenished based on usage. There are twelve bids for the product spanning three years. These data are presented in Figure 2. Figure 3 plots this information using an 'F' for the Firm's bid and 'C' for the Competition, a single company. The graph shows the reactions of each bidder to the last bid. When the competitor lost the tie on contract 1, it lowered its next bid by three cents per unit. After losing contract 2, the Firm reacted by matching the competitor's winning bid. The action and reactions continue to reduce the price until the ninth contract, when the competitor raises the price on two consecutive contracts. The Firm continued to lower prices until the eleventh contract, when it started raising prices. Finally, on the last contract, both companies started to increase their bids. The bidding patterns in this sequence of bids and similarly for other products form the basis for the probability distributions that are developed.

			Bid Awarded		2nd Best Bid	
No.	Quantity	Award Date	Company	Price	Company	Price
1	6,192	04/Year 1	Firm	$ 5.60	* Competitor	$ 5.60
2	3,888	08/Year 1	Competitor	5.57	Firm	5.60
3	2,592	10/Year 1	Firm	5.57	* Competitor	5.57
4	4,176	02/Year 2	Competitor	5.55	Firm	5.57
5	10,369	04/Year 2	Competitor	5.45	Firm	5.50
6	5,760	07/Year 2	Firm	5.40	Competitor	5.45
7	6,768	08/Year 2	Competitor	5.38	Firm	5.45
8	11,376	12/Year 2	Competitor	5.30	Firm	5.38
9	8,376	04/Year 3	Firm	5.30	Competitor	5.35
10	6,748	07/Year 3	Firm	5.27	Competitor	5.35
11	8,652	10/Year 3	Competitor	5.25	Firm	5.40
12	9,216	12/Year 3	Competitor	5.30	Firm	5.40

* If both companies bid the same price, the Firm won these contracts by a coin toss.

Figure 2: Summary of Information on Prior Bids.

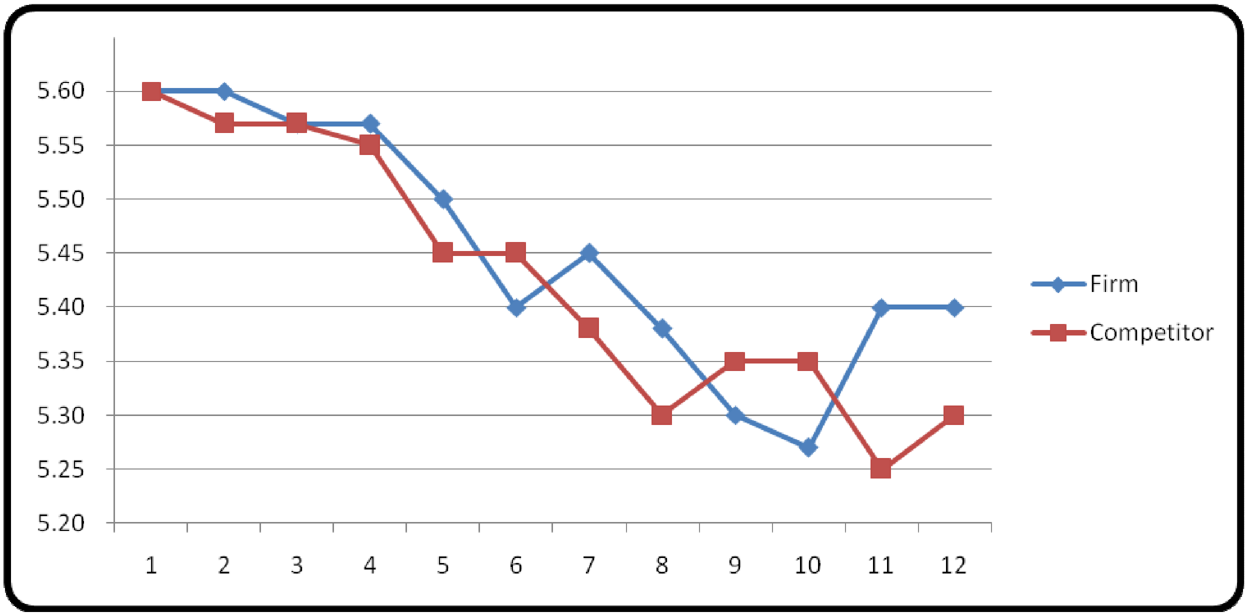
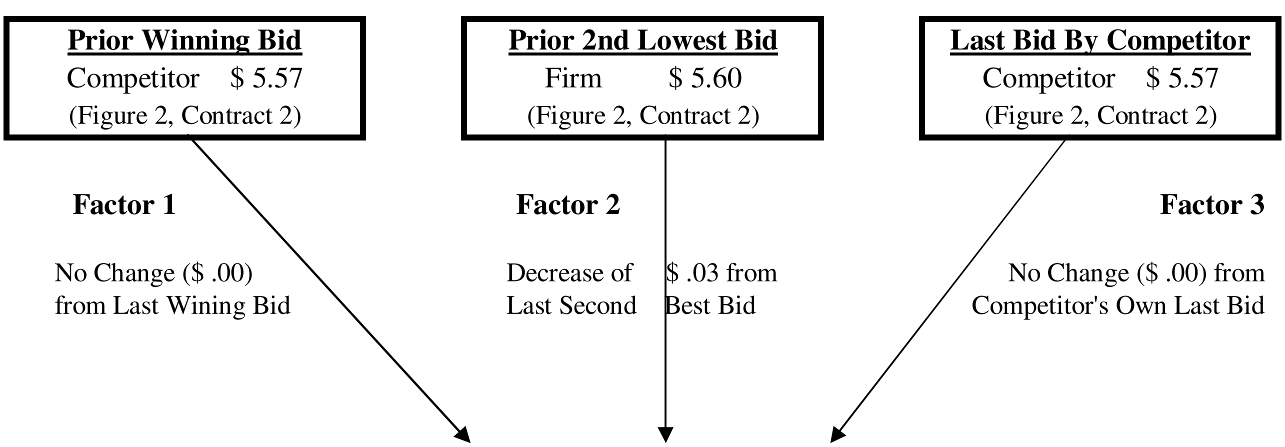


Figure 3: Graph of Bids for Product 1234.

Figure 4 illustrates the process for computing the incremental changes measuring the three factors relative to the next bid by the competition. Contract 2 in Figure 2 shows that the previous winning bid was $5.57, submitted by the competition; the prior second best bid was the Firm's $5.60, and the previous bid by the competition was $5.57. These are recorded in the top line of boxes in Figure 4. The third line from Figure 2 shows the competitor's next bid of $5.57 (the lower box in Figure 4), which is used in the calculation of the change between the competitor's next bid and

• Previous winning bid	Unchanged	Factor 1, Equation 1
• Previous second best bid	Decreased $ .03	Factor 2, Equation 2
• Competitor's last bid	Unchanged	Factor 3, Equation 3

These three distributions, one for each factor, are developed by repeating these calculations for all consecutive bids and combining them into one distribution. An example of the distributions derived using this method is given in Figure 5, Development of Distributions. The actual change in each factor is given in parentheses, the number of times that each change occurred is shown under the FREQ (Frequency), and the probability of that change is presented under PROB, which is computed using Equation 5.



Next Bid by COMPETITOR
Competitor $ 5.57
(Figure 2, Contract 3)

Figure 4: Details of the Development of Probability Distributions.

These incremental changes are measured relative to the last known bid in each category. The probability distribution for Factor 1 was developed by adding the incremental change relative to the winning bid to $5.30, the last winning bid, and recording its associate probability of occurrence. For example, there is a 27.27 % chance that the competition will drop its bid by two cents to $5.28 ($5.30 - $.02) on the next bid. This is repeated for each increment. Similarly, the distributions for Factor 2, the 'money left on the table,' and Factor 3, the competitor's strategy, are developed. These distributions are presented in the three tables across the top of Figure 5.

The probability distribution for the competitor's next bid (lower table, Figure 5) is constructed by adding the weighted probabilities for the three distributions representing the factors at the same price. The distributions in this example are combined weighting Factor 2 with .20 and Factors 1 and 3 with .40 each. For example, the probability that the competitor will bid $5.35 is the weighted sum of each factor for a bid of $5.35 [.40 time 27.27 (Factor 1) plus .20 times 16.67 (Factor 2) plus .40 times 18.18 (Factor 3) equals 21.52].

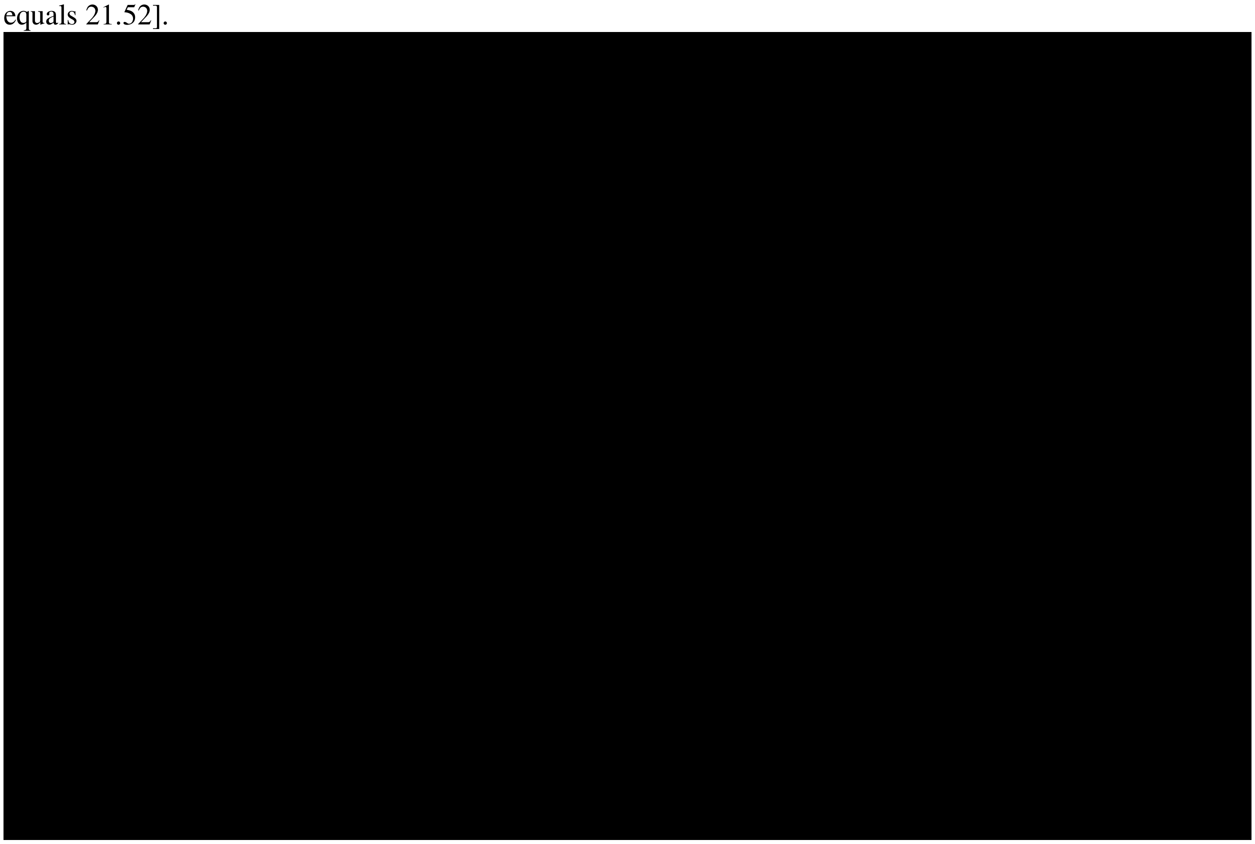


Figure 5: Development of Probability Distributions From Figure 2.

As described above, these weights are determined from a correlation analysis of historical data. The final distribution's last column, PROB(Winning), is the cumulative probability calculated using Equation 8. This indicates that a bid at $5.28 has a 67.59% chance of winning and that $5.27 has a 74.86% probability of winning. If management constantly bids at a given level, say 70%, then over a period of time the Firm should capture about 70% of the contracts. To control the market with such a dominant position, the Firm must continue an aggressive strategy of decreasing its price on each contract below the last winning bid. The result is lower prices and reduced profit margins to maintain a high market share. A special bidding analysis of the product indicated that a lower market share at a higher price was more profitable. This led to the increase in price on the twelfth contract and acceptance of a smaller market share over the long term.

VALIDATION OF MODEL

The bidding system was developed for a Fortune 200 company. The reports, graphs, and other parts of the decision support system were developed as the model was formulated and being tested. Criteria for the validation of the model were established along with procedures to monitor its performance. The example given in the paper was part of the original presentation made to the executive committee. In addition to the model, the results of simulation runs for five other products were presented to illustrate how the model worked in different types of markets ranging from stable to volatile with irrational and erratic behavior. Management accepted the concept and approved a six-month test to determine the accuracy of the model, achieving a given market share in an operational bidding environment. In the first test, the Firm's strategy was to continue to dominate a two-company market with a 70% share and bid at that level as specified by the model. After six months, the record showed that the company had a 72% market share from winning 73% of the contracts. Another six-month test was requested, resulting in a 67% market share from acquiring 68% of the contracts. Approval was then given to phase the model in for other products after similar validations. Eventually, twenty products representing eight different types of markets were incorporated into the bidding system. Each was carefully monitored with monthly reports. Results of the validation analyses indicated that the model was consistently within two to three points of the market share established as the goal by management.

With the success of the model and its direct effect on the bottom line, the corporate forecasting group developed a model for pricing contracts. This group, directed by a statistician with expertise in models using regression, had previously developed the entire set of sales forecasting models for all products. His sales forecasting model predicted the company's sales within 1 to 2% compared to the previous sales models that were usually off by 8 to 12%. Based on that success, the statisticians in the group worked for six months to develop a regression bidding model. For the four products that generated the most bidding revenue, the initial six month test results are presented in Figure 6. Each product's market share and revenues were compared based on the bids generated by regression model, the bidding model using the three factors, and the contract manager. The regression model failed to achieve the results of the bidding model described in Section 3.

Product	Contract Manager		Bidding Model Using 3 Factors		Regression Model	
	Market Share	Revenue (Millions)	Market Share	Revenue (Millions)	Market Share	Revenue (Millions)
A	71 %	11.3	73 %	12.2	52 %	5.1
B	31 %	7.8	34 %	8.5	18 %	4.2
C	46%	7.6	43 %	8.1	29 %	3.7
D	35 %	5.8	33 %	6.1	21 %	2.9

Figure 6: Comparison of Bidding Models.

The number of competitors varied depending on the product and market. This included many new entrants over ten years of operations, with some markets having as many as eight competitors. The model has responded to markets whether they are well behaved, stable situations or volatile environments. After using the model for six years, the director of contract administration, who originally requested assistance with the bidding problem, said that using the bidding model had significantly reduced the tension and stress of his job. Initially, the bidding model was directly responsible for over $64 million annually; this figure increased over the years to more than $300 million. An annual review of the bidding strategy for each product is presented to a joint meeting of product management, contract administration, and executive committee members. The bidding system is an integral part of the decision making process.

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Reviewer's Recommendation for Changes in Paper

Comment to the Author:
In this paper the authors describe a case study in which a model is used to decrease the risk in bidding on contracts. The model is based on statistical information based on the history of prior bids and has been validated thoroughly.

The article is easy to read and is relevant to both the scientific and business domains. There are a few minor improvements that the authors could make:

- The related literature section has many references to literature from before 2000 and therefore seems to be a bit outdated. I suggest that the authors update this section, or is there no current research literature available?

Added the following references to paper:

Chen, F. (2007), "Auctioning Supply Contracts," Management Science, 53, 10, 1562-1576.

Engelbrecht-Wiggans, R. and E. Katok (2007), "Regret in Auctions: Theory and Evidence," Economic Theory, 33, 1, 81-101.

Engelbrecht-Wiggans, R. and E. Katok (2009), "A Direct Test of Risk Aversion and Regret in First Price Sealed-Bid Auctions," Decision Analysis, 6, 2, 75-88.

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Skitmore, M. (2002), "Predicting the probability of Winning Sealed Bid Auctions: A Comparison of Models," Journal of the Operational Research Society, 53, 1, 47-56.

- The prior winning bid of $5.70 in figure 4 doesn't match with figure 2 where it says 5.57

Modified Figure 4 by changing $5.70 to $5.57, the competitor's bid.

- The probability of winning in figure 5 (lower table) on third line reads 29.71, shouldn't this be 49.71?

Changed 29.71 to 49.71 in Figure 5.