Investigation of Bid Price Competition Measured through Prebid Project Estimates, Actual Bid Prices, and Number of Bidders

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Abstract: Many practitioners today are faced with the task of advising clients on matters that may affect the number of project bidders. An appropriate question may be, does a restriction of bidder participation negatively impact project costs through limiting competition, and to what degree? Intuition and anecdotal evidence suggest that with an increase in the number of bidders vying for a project, the more competitive the low bid offer will be. There is little published evidence and analysis on bid competition impacting cost-effectiveness, although there are numerous reports replete with arguments, assumptions, anecdotal evidence, and bias. This paper critically evaluates public projects, bid under a condition of free, open, and unfettered competition. This paper presents a quantitative analysis of the impact of reduced competition on project bid prices. By selecting a single building type, designed by a single firm, with prebid estimates prepared from the same estimating database, over a limited time period, the investigation attempts to control model variance. The study found that reducing the number of bidders will result in increased project bid prices.

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Introduction

Few research studies have been conducted to evaluate the relationship between the number of bidders on a project and the bid price for the work. The few studies that have been performed have left questions relative to the data utilized and the "signal-to-noise ratio," or as defined in the *Harvard Business Review*, "(t)he extent to which the variable of interest is obscured by other variables" (Thomke 2003, p. 75). By investigating the relationship between the number of bids and the deviation from the owners' published budget, extraneous factors like different building types, fluctuations in market conditions, differences in market areas, differences in the design documents, as well as the quality and consistency of the prebid estimate, can all distort the study's ability to isolate the "variable of interest." The investigation of projects with similar design standards, prepared by the same design firm, in the same market sector, within a limited period of time, with estimates prepared under a single professional estimating standard, allows this research to minimize extraneous noise from these variables.

This paper provides several significant contributions. The paper develops a regression model to quantify the impacts of greater or less competition within a robust bidding exercise. The regression analysis also identifies the nature of varying bid activity dynamics, as the loss or addition of bidders, and discovers a strong nonlinear relationship.

This research has been undertaken to attempt to replicate the findings and positions of earlier, published and unpublished investigations, within a controlled group of projects where the "variable of interest," the number of bidders, can be analyzed discretely.

Background

In August 2000 an Architectural-Engineering-Construction Management firm in upstate New York had been retained to plan and manage the design and construction of a major expansion and reconstruction of the municipal courthouse construction program. During the course of this work, the owner, a municipal county government, directed that firm to investigate the appropriateness for using a Project Labor Agreement (PLA) for the work. The writer was then asked by the construction manager to conduct the investigation. This evaluation required the analysis of numerous considerations, primarily involving cost implications of adoption of the labor agreement.

It was discovered that there was little published evidence or analysis on bid competition and its impact on project costs. It became apparent that simple, straightforward information was needed to evaluate the impact on publicly bid projects where a restriction on open and unfettered competition could occur. This restriction might be in the form of an entity simply wanting to receive bids from a select number of "pre-qualified" bidders. Under any scenario, it is posited that a restriction on competition would have a negative influence on hard-dollar, low-bid pricing. These possible restrictions on free, open, and unfettered compe-

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tition may be grounded in what are considered good business decisions. There may be overriding factors that drive an owner's decision to limit competition through some form of restriction on qualifications. For example, one could view the requirement for a contractor on a public project to provide a bid bond, and subsequent performance and payment bonds, as a restriction on competition. However, the trade-off of possibly having an unbonded contractor performing the work may not adequately protect the public interest. Hence the effect is that this limitation restricts the competitive field of bidders. Such a restriction has been found to be in the public's best interest.

In the hard-dollar, low-bid construction industry, there has always been a continuing momentum in how various constituents vie for a competitive edge. The strategies resulting from this momentum can result in increased competition. Theoretically, the strategies of this competition ultimately benefit the general public through creative construction performance and lower bid prices. The question of lower costs is investigated in this paper.

Project Labor Agreements

Recently the proposition for the widespread use of Project Labor Agreements has found its way into a broad sector of the construction market. This phenomenon has led to significant debate, question, and pressure on the traditional advisors to public owners, as well as their architects, engineers, and construction managers.

The PLA is an agreement made on behalf of a project owner with the local unions' representatives that typically ensures that all project employment, including all "new-hires" to the contractors' workforce come from the union hiring hall. In times of limited resources, restricting labor on public works projects to those workers who are either existing union members, or willing to join the union ranks, can restrict the number of bidders who either can, or are willing to modify their customary methods of business, *adopting* union rules, and *adapting to* the union work rules as defined in the PLA.

Governmental Policy Implications

It was prior to the Civil War that this country's public bidding laws were enacted. The purpose was to formalize the public procurement process, to "deter government officials from giving business to friends and associates and to prevent fraud by government employees who award contracts for public works" (Abrams 1985, p. 26).

Recently there have been various Executive Orders, issued at both the national and state levels, taking positions on the use of PLAs. Architects, engineers, and construction managers may be called upon to make evaluations as to whether or not a PLA will offer a reasonable expectation for the advancement of the objectives and goals of competitively bidding public works projects. Those objectives and goals of competitive bidding have been spelled out in numerous summaries. Those goals may include: "'guard(ing) against favoritism, extravagance, fraud and corruption, to prevent the waste of public funds, and to obtain the best economic result for the public'; 'inviting competition'." The purpose of the competitive bidding procedure is to "secure the best work… for the lowest price practicable… and not for the enrichment of bidders." The goals are also to "'stimulate advantageous marketplace competition' finding the 'lowest responsible bidder whose offer best responds in quality, fitness, and capacity to the particular requirements of the required work'" (Worcester Municipal Research Bureau 2001).

It is the purpose of this study to answer one of these questions, investigating in a systematic way the relationship between the number of bid offers received on bid day, and the resulting cost deviation from the prebid project estimate. If there is a restriction placed on a project that results in a lower number of willing bidders, will there be a measurable concomitant increase in the construction price on public projects?

This research analyzes the number of project bidders versus the price deviation from the owners' published prebid estimate.

Framework for the Study

This study employed the assessment of 19 major public works projects, with 438 bids and over \$158 million in construction value. Each project was a public educational facilities project, in New York State, with bids received from, and contracts awarded to, both union contractors and merit shop contractors. The examination of the bid results provides a data source to evaluate the impact on the owners' prebid project budget as a function of bidder competition, measured in the sheer number of bids received. Intuitively, the dynamic of construction bidding indicates that the greater the number of competing bidders, the greater the opportunity to arrive at the most cost-effective construction offer and building technique. The purpose of this study is to present a statistical evaluation of whether or not fewer bidders will likely result in higher bid prices.

The model of this study provides a framework to analyze the bid price; the independent variable; and its deviation from the prebid estimate, measured as a percentage of a project's low, responsive, responsible, and awarded bid price. The number of bids received on each of the separate contracts analyzed forms the dependent variable.

To clarify the independent variable, deviation from prebid estimates, if the prebid estimate was \$1,000,000, and the bid price offered was \$950,000, then the deviation value would be 0.95. Likewise if the bid offer were \$1,030,000, the deviation would be 1.03.

Since it is difficult to find public works construction projects that have great similarities, earlier studies have faced difficulties in providing systematic analysis. "(S)uch studies would be difficult to produce, given the diversity of such projects and the consequent variety of factors that can affect the costs" (Worcester Municipal Research Bureau 2001, p. 8). This challenge has been addressed in the current study.

In order to minimize the variability in the data, all projects selected for evaluation had been bid under a relatively uniform and formal procedure. According to Thomke, results "can be distorted when 'noise'—variables other than the one being tested—influence results in ways that can't be controlled or measured" (Thomke 2003, p. 75). Since each project selected for inclusion in the study was a publicly bid school project, many variables that could impact bid prices were controlled. These include variables such as: a mandated minimum bidding period, material and equipment substitution or equivalency requirements, and a published minimum prevailing labor wage rate, among others. In addition, each of the projects selected for study was designed by the same firm; with the prebid estimate prepared from the same database; was bid in the same region; with the same basic structures and components; and in a limited period of time.

Section 103 of the New York State General Municipal Law

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(McKinney's 2000) requires separate bid documents be prepared and separate bids received for three categories of work. Those separate contracts are

1. Heating and ventilating,
2. Plumbing and gas-fitting, and
3. Electrical.

For the purposes of this study, and since it is an industry convention, minimally a fourth contract category is recognized and evaluated, the general contract. Therefore each major public construction project in New York State has at a minimum four prime contracts. It is not unusual to have additional prime contracts, such as site-work. On projects including both new construction and areas of renovation, an example of an additional contract might be the reroofing of the existing structure. In order to control the variables influencing the research, projects with no more than five prime contracts were evaluated.

However, the hypothesis relative to the market forces of increased competition resulting from an increase in the number of bid offers is present across contract categories (General Construction, HVAC, etc.). As such the categories are not analyzed individually but rather as a group. The statistical reasons for this are discussed in the following section.

Hypotheses

There are many definitions of hypothesis testing, however, they can generally be captured in that they are procedures for making rational decisions about the reality of events. Specifically, does one believe there is an effect from one variable upon another? In this case, does the number of bidders participating in a bid competition result in lower bid prices experienced by the project owner? The research belief is that there is likely a relationship between these two factors, and it is statistically explored through the development of a hypothesis, which is then tested.

In this study the first hypothesis holds that with a reduced number of bidders there will be an associated increase in project price. Regardless of whether the reduction is due to material limitations, bid timing, overall contractor disinterest, or an imposed limitation based on labor policy, the fewer bid offers received will, on average, result in a higher cost of award to the low, responsible, responsive bidder.

The dynamics of the bidding process include not only the prime contractors bidding the work, but also the various subcontractors and suppliers who provide services and goods on the project. During the bid period, active competitive pricing from all of these entities impact bid prices: contractors, subcontractors, and suppliers. One might suggest that with increased competition, through a wider field of prime bidders, there would be greater interaction within and among the contractors, subcontractors, and suppliers, resulting in a lowering of the average bid price.

Null Hypothesis

The null hypothesis (H_0) of the research is: In the School Building Sector of the Publicly Bid Construction Industry, in New York State; based upon a measure of competition through the number of project bids received, there will be no measurable correlation between number of bidders and deviation measured by the relative difference between the owners' prebid project estimate and the low responsible, responsive bid price offered.

Research Methodology

Method of Analysis

The research methodology for this study was developed into a multistep series. The first step was to perform a literature review to determine if sufficient evidence existed supporting the theory that increased competition, as measured by the number of bids received, would result in more competitive bids and lower costs.

The second portion of the study investigated the correlation between the increased number of bids and the lowering of the low bid and average bid prices. The study included 438 bids, received on 19 separate educational building projects, totaling almost $158 million in awarded contracts. The bids were received from over 80 separate contracting companies. These bids resulted in the award of 84 prime contracts.

These two steps are followed by an exploration of the data collected, and a discussion of the implications of this research. An attempt was made in this research to simplify the analysis of the data, and to avoid "logistical and computational overload" (Skitmore et al. 2001, p. 149).

Exploratory Study

The Roswell Park Cancer Research Facilities project in Buffalo, N.Y. was studied several years ago (ABC 1995). An investigation was conducted to determine if reduced competition, measured in the number of bidders, resulted in higher bid prices. It was reported that with their sample, a correlation existed between the number of project bidders and relative deviation between the project's prebid estimate and the low bid received. This study suggested the rate of cost increase for each bidder lost was over 3% (ABC 1995). A number of other studies have found similar results. Generally however, these studies are performed with nonhomogeneous data sources, which lead to questions of influencing factors that may have caused the reported relationship (Park and Chapin 1992; Runeson and Skitmore 1999).

Unfortunately, the database for these studies included a wide variation in project size, type, and location. As suggested by Thomke, "The noise can drown out the signal, making it hard to determine whether the variable you're testing for is the one that actually causes the effect you are measuring" (Thomke 2003, p. 72). Even though statistical significance was reported, these considerations, among other factors, suggested the need for further study with a more homogeneous sample of projects.

Data Collection

The data for the study were collected through retrieval and analysis of the bid results for 19 public works educational construction programs in upstate New York. The data are gathered from the public record, and were made available by the projects' design firm. The data collected from the 19 separate capital building programs focused on the value of the awarded contract (bid) prices, each project's budget, and the number of bidders for each project. Eighty-four (84) contracts were awarded. The data from these projects formed the basis of the data analyzed. Within this global data set, there was a subset of data where, not only the low bid price, the prebid estimate, and number of bidders was available, but the entire set of bid results were also available. This subset of data consisted of 243 bids resulting in 48 awarded contracts.

In the institutional sector of the public construction market, for

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Table 1. Research Sample Bid Data

Category	Total low bids (dollars)	Prebid estimate (dollars)	Bidders	Contracts	Average no.	Average deviation (%)
General	111,649,192	107,129,911	99	21	4.71	4.22
HVAC	20,414,614	19,685,386	101	20	5.05	3.70
Plumbing	9,268,727	8,932,908	92	20	4.60	3.76
Electrical	15,968,503	18,015,484	126	20	6.30	−11.36
Sitework	1,671,215	1,973,217	20	3	6.67	−15.31
Totals	158,972,251	155,736,906	438	84	5.21	2.08

an owner to make an informed decision relative to undertaking a project, a budget must be established. Establishing this budget is generally done in a series of estimates provided to the owner by their technical advisors, generally the architect/engineer, but often by the construction manager and/or an independent cost estimating firm.

In recent years there has been a relatively active design and construction market for K–12 educational facilities across the nation. In New York State, there are laws, rules, regulations, and standards guiding procedures for the design of these schools, and for the solicitation and receipt of competitive bids from contractors. These conditions allowed the opportunity to collect data on a large number of similar projects, completed within a limited time period, under a uniform bidding procedure.

The public bidding market generally allows any responsible and responsive bidder to submit a bid and be considered for contract award. At the bid opening, a representative of the owner reads and records the bid offer from each contractor submitting a proposal. This record is available for public inspection. Based upon these bid offers, the architect and/or the construction manager will review the bids relative to the projects' budgets and the bidders' qualifications. Based upon the findings of this review, the owner will generally follow one of two paths: (1) accept the bids and award contracts, at which time the project proceeds to construction, or (2) reject the bid proposals, and either rebid the work or abandon the project.

Profile of the Sample

The projects were selected to minimize variance in the sample studied. All of the projects were institutional projects in upstate New York. In fact all of the projects were schools; new construction, renovation, and addition projects. Each project was designed by the same architectural and engineering (A/E) firm. The projects were all provided with a prebid estimate. The estimate was prepared by either an independent estimating firm regularly used by the A/E, or was prepared internally by the A/E design firm, utilizing, by and large, the same database and estimating procedures used by their external consulting estimator. All of the projects were designed and bid between 1996 and 2000, and attracted in many instances the same group of bidders.

The question arises as to the size of the sample required for the research work. This consideration is one of the "power" needed for the statistical procedures to be employed in the study. The following summary outlines the considerations of sample size, statistical procedures, and assurances of discovery of significance where such exists.

The primary concern of most statistical procedures is to maintain a high probability of avoiding an unsubstantiated finding of a "statistically significant result" where none exists. This is commonly referred to as avoiding a Type I error. The Type I error occurs when the experiment or research finds a positive result that is not true.

The second statistical error, a Type II error, occurs when there is a relationship between the elements being investigated, however, none presents itself in the research findings. While a situation may exist that a false null should be rejected, it is possible that the statistical investigation may be unable to detect this result and present such a finding if there is inadequate evidence. The protection against this form of flawed research is to improve the experimental research design, to ensure the investigation has adequate "power" to detect the results if they do exist.

The evaluation of the power of this research is to ensure an appropriate sample size. An adequate sample is needed to secure the detection of statistical significance where it exists, or in other words to assure the research design is powerful enough to reject a false null, H_0.

An essential consideration in determining the "power" of an experiment or research investigation is the effect size. This is a function of the standard error, which is computed based on a particular sample size. This is of course the answer sought in the investigation of power. As such, absent a fixed sample size, there are alternative methods of estimating the effect size.

Several methods to determine the power of an experiment rely on data referred to as *special conventions*. While one may choose to use the approach of a *special convention* selection, one of the most reliable approaches is to use data from prior research. In the case where the primary statistical approach is a correlation study (the fundamental statistic of this research) the correlation coefficient, ρ, is the equivalent of the effect size, d. In the case of human behavioral research (in this case bidders' reactions to increased competition), correlation coefficients in the range of 0.20–0.50 are not uncommon. This example, along with reference to the works of other researchers, has led to the selection of a ρ, of 0.35 for the sample size estimate.

The noncentrality parameter, δ, is a function of the effect size, d, and the sample size. If both the noncentrality parameter and the effect size can be established, then the recommended sample size can be estimated. The published "power" tables present the noncentrality parameter for different levels of significance desired. In the case of this research, an α level of 0.05 is selected for a two-tailed test, or we therefore have a 95% probability that we will not report a correlation of the variables, if none exists. Additionally, the probability of experiencing a Type II error may be selected by the researcher, which is then used to determine δ, the noncentrality parameter. The minimum power determined for this research to be acceptable was 0.80, or an 80% probability of the discovery of an effect, if one truly exists. In this case the parameter has been selected for this level of protection against a Type

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Table 2. Descriptive Statistics of Overall Sample Contracts

	Mean	Standard deviation	N
Number of bidders	4.82	2.013	84
Deviation from estimate	0.97928	0.238040	84

II, 80% *power*. This then yields a δ, noncentrality parameter of 2.80 for a two tailed α of 0.05 (95% confidence).

The sample size is then estimated from the following formula:

$$\delta = \rho\sqrt{N-1}$$

$$2.80 = 0.35\sqrt{N-1}$$

or

$$(2.80/0.35)^2 + 1 = N = 65$$

Therefore the minimum recommended sample size for the research being conducted was 65 case bids.

Since it is established that the total number of low bidders in the sample is 84, this response would present an experimental power of approximately 88%. This analysis indicates that the design of this research offers appropriate power against the occurrence of a Type II error. It also highlights the caution to avoid "splitting" the sample into subcategories (i.e., general contractor versus electrical contractor, etc.) since the categorical sample size is thus decreased, increasing the probability of encountering a Type II error.

Evaluating the data within a categorical context is possible. This will offer insight into data relationships, however, if the sample were split to include only one category of bidder, the power of the experiment then drops from 89% to approximately 34%, increasing the likelihood of a Type II error. Continuing this example, if the respondent group were divided into four groups for analysis, the Type I error would continue to be protected by the statistical analysis chosen. However, the potential of a Type II error increases considerably, from 12% to over 65%.

In order for the analysis to be meaningful it is essential to have a sample size appropriate for the statistical analysis being used. For a moderate effect size of ρ, of 0.35, and a desired power of at least 0.80 (80%), with an α level of 0.05, a sample size of 65 participants would be required in this study (Howell 1997). The total number of 84 awarded contracts formed the low bidders' sample, exceeding the minimum recommended sample size of 65. This sample of awarded bids was out of the total number of bid proposals submitted of 438.

The sample was therefore comprised of 84 contracts awarded (Table 1). The distribution is 25% general construction contracts (n=21), 24% heating and ventilating contracts (n=20), 24% plumbing contracts (n=20), 24% electrical contracts (n=20), and 4% site-work contracts (n=3). From the total bids submitted, 23% came from the general contractors and HVAC contractors, while 21% came from the plumbing contractors. While only 24% of the awarded contracts went to the electrical contractors they represented 29% of the total bids received. The remaining 5% of the bids were received from the site-work contractors. The price range of the awarded contracts was $73,000–$13,973,000; with an average price of $1.9 million.

Table 3. Pearson Correlation-Number of Bidders Versus Deviation from the Estimate

		Number of bidders	Deviation from estimate
Number of bidders	Pearson correlation	1	−0.320[a]
	Sig. (2-tailed)	—	0.003
	N	84	84
Deviation from estimate	Pearson correlation	−0.320[a]	1
	Sig. (2-tailed)	0.003	—
	N	84	84

[a]Correlation is significant at the 0.001 level (2-tailed).

Results

Study Findings

Within the data set of 84 projects, the number of bidders, the low (awarded) bid, and the owner's prebid estimate were available. For a subset of the data, there was a group of 48 contracts where in addition to the foregoing data, the bid price from each of the bidding contractors was available. In this subset of data there were 243 bids that, in total, showed a standard deviation of 0.31 and a mean of 1.07. This suggests that on average, the bid price received exceeded the published prebid estimate by 7%, considering not only the low bid contractor, but also all the bids offered.

The complete data set (438 bids; 84 contracts) represents the core data used in the evaluation. The low bid deviation from the prebid estimate, for the 84 awarded contracts, is presented in Table 2.

The data from the 84 awarded projects was then evaluated. A correlation analysis of these data was performed. The results of this analysis are presented in Table 3, and indicate that there is indeed a statistically significant relationship between the number of bidders on a project and the low bid received, relative to the project budget.

This correlation indicates that of the 84 project bids investigated there is a 99.7% probability (1.000–0.003) that the relationship between these two factors did not occur by chance alone. It also indicates that the relationship is a negative correlation,

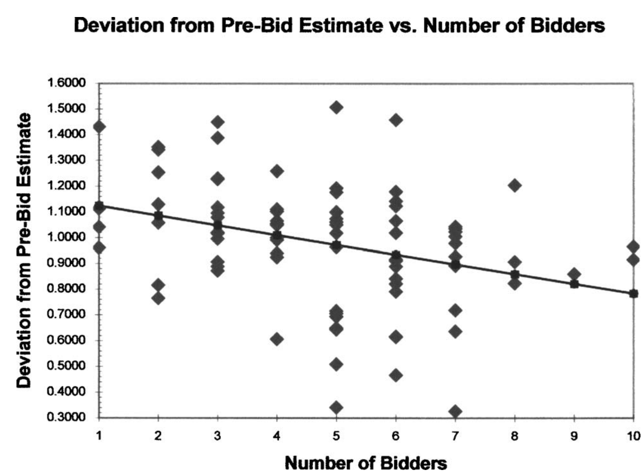

Fig. 1. Regression plot of number of bidders and deviation from estimate

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Table 4. Analysis of Variance—Low Bid Deviation Versus Number of Bidders

ANOVA[b] model		Sum of squares	DOF	Mean square	F	Significance
1	Regression	0.483	1	0.483	9.386	0.003[a]
	Residual	4.220	82	0.051	—	—
	Total	4.703	83	—	—	—

[a]Predictors: (Constant), number of bidders.

[b]Dependent variable: Deviation from estimate.

Table 6. Analysis of Variance—Average Bid Deviation Versus Number of Bidders

ANOVA[b] model		Sum of squares	DOF	Mean square	F	Significance
1	Regression	0.019	1	0.019	0.198	0.657[a]
	Residual	23.176	241	0.096	—	—
	Total	23.195	242	—	—	—

[a]Predictors: (Constant), number of bidders.

[b]Dependent variable: Deviation from estimate.

(−0.320). This negative correlation indicates the higher the number of bidders participating, the lower the bid price.

The core of the investigation, the relationship between the independent variable (*bid price deviation from the prebid estimate*) and the dependent variables (*number of bidders*), exhibited a significant correlation.

It is fine to establish that there is a correlation, but the real question is one of impact. The question then becomes, what is the relationship of bidding activity and the prediction of the impact on the projects' cost (Fig. 1). The data were then subjected to a linear regression analysis to determine the "predictive" impact of this relationship. The regression tells the rate of decrease in project cost that may be expected on a per bid basis for additional or fewer bidders. In other words, if there were one less bidder, the predicted impact on the project's budget would be of interest. The regression data are presented below in Tables 4–6.

The regression model tells us that, on average, for each bidder lost from the competition there will be a 3.79% increase in project cost. The result is that for the study's main hypothesis, the null is rejected. As the number of bidders is increased, there is a concomitant reduction in the bid price offer from the low bid contractor.

The second hypothesis is that with an increase in the bidding participation, there will be a reduction in the average bid received for each project. This is analyzed in the same fashion, however, this evaluation uses the complete bid tabulation data available for the data subset where the prices of each bidding contractor were available. The data set for these projects represent 243 bids. The first computation for all bids received is for the correlation of each bid deviation from the prebid estimate, against the number of bids received for each contract.

It was found that there is no statistically significant correlation between the number of bids and the deviation from the prebid estimate. An ANOVA was performed on this data and there was no significant relation found (sig.=0.657). This result is presented in Table 6. There is no reduction in bid prices overall, as the number of bids increase; the average bid price does not drop. Therefore the current data do not support the second hypothesis, and the null cannot be rejected. There is no statistically significant relationship between the number of bidders and an associated reduction in the average bid price. This is visually represented in Fig. 2, the scatter-plot of each bid's deviation from the estimate versus the number of bidders. Although there is a slight downward slope in the regression line, the data do not support a statistically significant finding.

Exploration of Data

The results of this research have established a significant relationship (sig. 0.003) between the lowering of the low bid on the project and an increase in the number of bidders. While there was a relationship, was the relationship linear? Upon investigation it was found that the rate of cost reductions changed with the increase in bidders.

An interesting finding was noted when the data were analyzed in a curvilinear regression, the goodness of fit of the data improved significantly over the simple linear regression. The model summary is presented in Table 7, below.

As shown, the correlation coefficient, R, has increased from the linear regression value presented in Table 3 of 0.320, to the curvilinear value of 0.617. The relationship between the number of bidders and the deviation with the prebid estimate varies nonlinearly. The rate of reduction in bid prices varies with the increasing number of bidders (Fig. 3).

The data subjected to the curvilinear analysis show that the rate of reduction varies with the increase in the number of bidders. It was observed that as the number of bidders increases, the rate at which the low bid price dropped, increased. This phenomenon held true through the addition of the sixth bidder, at which time the curve begins to flatten. The relationship of increased bidders and the rate of price reduction is plotted in Fig. 3 and presented in Table 8.

As shown in Fig. 3, when only one bid is received, the project is expected to be approximately 15% over the prebid estimate. As the number of bidders increases to four, the bid prices will approximate the prebid estimate (101%). This is presented in Table 8.

The best-fit curve, Fig. 3, suggests that prices dropped slowly at first with an increase in bidders. Moving from a single bid, to receiving a second bid, there was a 4% price drop, while the third bidder dropped the price another 4%. As the number of bidders

Table 5. Regression Coefficients—Low Bid Deviation Versus Number of Bidders

Coefficients[a] model		Unstandardized coefficients B	Unstandardized coefficients Standard error	Standardized coefficients Beta	t	Significance
1	(Constant)	1.162	0.065	—	17.995	0.000
	Number of bidders	−3.79E−2	0.012	−0.320	−3.064	0.003

[a]Dependent variable: Deviation from estimate

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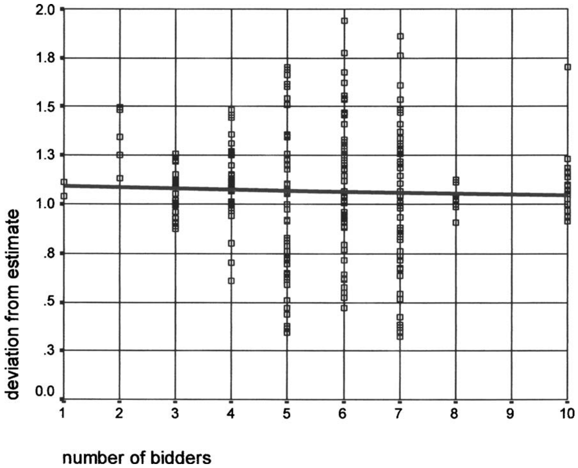

Fig. 2. Number of bidders versus each bid's deviation from the estimate

increased, the rate of price reductions also increased. Once the fourth and fifth bidders joined in the competition, an additional 6% reduction with each additional bidder was seen. The sixth bidder yielded another 4%. This totaled a 24% reduction from receiving only a single bid, to the robust competition of six bidders actively pursuing the contract. The seventh bidder added another 2% reduction, while the eighth bid yielded an additional 1% reduction, at which time the curve flattened to near zero.

Discussion

This study demonstrates and quantifies the cost savings achieved as the dynamic competition of a robust bid exercise is conducted. The old standard of "we'll get you at least three bids for each contract" is shown to fall short of marketplace free, open, and unfettered competition.

If there is any restriction on competition, there is to be an expected price penalty paid. This restriction can come in the form of prequalification, local preferences, shortened bid period, poor advertisement and distribution of plans, or any other form, and the net effect will likely be the same. The market will not have been provided with the opportunity to tease out the most efficient, creative, and cost-efficient construction procedure.

As the number of bidders increases, it is intuitively obvious that there will be a commensurate number of additional material suppliers and subcontractors involved with the bidding process. As the additional prime bidders involve their favorite suppliers and subcontractors to the project, the overall competition increases at all levels. The more interaction among the prime contractors and subcontractors, the more opportunity for the cost implications of that creativity and competition to be carried through to the low bid offered.

The implications of the responsibility on the architect, engineer, construction manager, and/or purchasing agent are clear. If

Table 7. Statistics for the Curvillinear Regression of the Data

Model	R	R square	Adjusted R square	Standard error of the estimate
1	0.617[a]	0.380	0.367	0.065632

[a]Predictors: (Constant), number of bids.

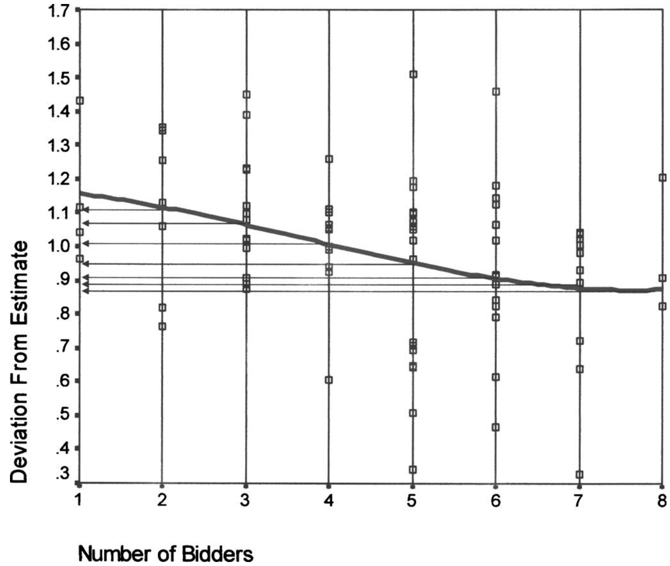

Fig. 3. Curvilinear relationship number of bidders versus deviation from estimate

they are unable to generate sufficient bidding interest, their client will pay the cost on bid day. The disinterest could be poor timing of the bid, when everyone is busy. It may be too short a bid period to properly distribute plans and bid the work. Project timing could be as simple as a contract being bid concurrent with other work, causing bidders to choose where their estimating resources are spent, and passing on a project.

A lower number of bidders may be the result of no one wanting to work for a particularly difficult owner, architect/engineer, or construction manager. This study shows that the assurance to an owner that he has gotten the "right price" because he received at least "three bids," therefore the competition of three "keeping the bidders honest," is less than what it might be.

Regardless of the reasons for the limitations, this study demonstrates that free, open, and unfettered competition will have the highest probability to achieve the goals of competitive bidding to "guard against favoritism, extravagance, fraud and corruption, to prevent the waste of public funds; to obtain the best economic result for the public"; "inviting competition" to "secure the best work… for the lowest price practicable… and not for the enrichment of bidders"; to "stimulate advantageous marketplace competition" allowing the public owner to find the "lowest responsible bidder whose offer best responds in quality, fitness, and capacity to the particular requirements of the required work."

Table 8. Bid Reduction with Increasing Number of Bidders

Number of bids	Low bid deviation from estimate	Drop in bid low price
1	1.15	—
2	1.11	4%
3	1.07	4%
4	1.01	6%
5	0.95	6%
6	0.91	4%
7	0.89	2%
8	0.88	1%
9+	0.88	Negligible

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Limitation and Future Research

Overall, the findings of this research work suggest a number of areas for future study. First, a more detailed research study investigating facilities other than public buildings may be appropriate. While the results of this study reflect, in general, the findings of earlier work, there is a limitation in that it addresses specifically lump sum, publicly bid construction. The applicability of the findings to linear construction has not been investigated (i.e., sewer and water lines). Linear work is traditionally performed under a unit price format, with the bid period dynamic considerably less complex, and in many ways less chaotic than a building contractor's office on a typical bid day. Linear construction is, by and large, self-performed to a much greater extent than vertical construction with its myriad of specialty subcontractors.

The present research relied upon the prebid estimates prepared by the architect's office and their estimating consultant. The accuracy of prebid estimates is always a matter of question. The accuracy should be viewed in light of how well the estimate compares to the low bid offered on bid day (of course with appropriate allowances for construction contingencies). The accuracy of an estimate generally is impacted by three major elements: who prepared the estimate, how it was prepared, and the level of information known at the time of the estimate (Oberlender and Trost 2001).

The current research studied the deviation between the low bid and the prebid estimate, compared to the number of bidders, since in the earlier studies, these were the metrics that were evaluated. The established relationship of this work is between the low bid offer, and the number of bidders. The current research has established that the number of bidders does not impact, in a statistically significant way, the average bid price for the projects. The average price of the bid offers could be viewed as a measure of what the group of bidding contractors believe to be the fair value of the work, or what the bidding group views as the "right price." Rather than use the theoretical "prebid estimate" for the analysis, with an adequate data pool the actual average bid price established on bid day, within the heat of active competition, may provide an interesting insight into bid competition.

The evaluation of the final project cost compared to the bid day offer was beyond the scope of this study. However, future research into this area may offer further insight into the question of how many bidders are required to achieve the highest balance of initial price competition and final project cost.

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