CORE COMPETENCIES AND SKILLS-BASED COMPETITION AMONG GENERAL CONTRACTORS

by

JOSEPH GIOIOSO

B. S. Civil and Env. Eng., Cornell University
(1988)

Submitted to the
Sloan School of Management
and the
Department of Civil Engineering
in Partial Fulfillment of the
Requirements of the Degrees of

Master of Science in Management
and
Master of Science in Civil Engineering

at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
June, 1992

Signature of Author________________
Sloan School of Management
May, 1992

Certified by________________
Fred Moavenzadeh
Professor of Civil Engineering

Certified by________________
William F. Pounds
Professor of Management

Accepted by________________
Jeffrey A. Barks
Associate Dean, Master's and Bachelor's Programs
Sloan School of Management

CORE COMPETENCIES AND SKILLS-BASED COMPETITION AMONG GENERAL CONTRACTORS

by

JOSEPH GIOIOSO

Submitted to the Sloan School of Management and the Department of Civil Engineering in partial fulfillment of the requirements for the Degrees of Master of Science in Management and Master of Science in Civil Engineering

ABSTRACT

This thesis investigates the importance of core competencies and skills-based competition among general contractors in the Boston Public Works Construction Market. Core competencies are defined here as a skill or skills-set which provides access to a wide variety of markets, makes a significant contribution to the perceived customer benefits of the end product, and is difficult for competitors to imitate. Skills-based competition is defined as a competition where the contractors who possess skills which most closely match the requirements of a given project will hold an advantage in that competition.

The motivation for this investigation was twofold: first, as a highly fragmented industry with low technical content, public works contractors are believed to have little competitive advantage vis-a-vis their competitors. Secondly, industry authors and working members both speculate that contracts awarded by competitive bid, as in public works construction, do not typically yield the most qualified contractor as low bidder.

The research was based on survey results from, and personal interviews with, thirty Boston-area industry members, including general contractors, subcontractors, public authority representatives, and design engineers. The results indicated that the firms studied did not typically possess core competencies in the eight construction and management categories studied. Furthermore, no significant correlation was observed between the proximity of a firm's bid to the low bid and how closely a firm's skills set matched the most difficult aspects of a project: firms which were considered highly skilled did not approach the low bid any more than the lower ranked firms. The differences between construction and management skills are analyzed, and other factors which may influence project bidding are also explored.

Thesis Supervisors: Fred Moavenzadeh, Professor of Civil Engineering
William F. Pounds, Professor of Management

ACKNOWLEDGEMENTS

I would like to thank the following people: my wife Ann, whose patience and understanding helped me greatly; my parents, for their support of my entire education; and the industry participants who provided valuable input to this thesis.

TABLE OF CONTENTS

Chapter 1: INTRODUCTION

The competition in public works construction is very different from the competition in most other industries. The General Contractors who compete to sell their product, construction services, must provide a product which exactly matches the requirements which the purchaser has specified. The contractors successfully sell only a small number of products (projects) each year, and can typically expect several other firms in competition on any given sale. Among the firms who are prequalified (by the purchaser's standards) to bid on the contracts, the only criterion used to select the winner is the price at which the services are offered. The purchasers of the products are all government agencies, and their propensity to support a proposed project is often influenced by political pressures and the availability of funds. It is in this context that public works general contractors compete.

General contractors actually compete against each other infrequently, and that competition is largely defined by the bidding process. The bidding process determines the volume of work which a firm will perform, and the likely profit margins which the firms will reap. The bidding process is thus of vital importance to the general contractors (all future references to general contractors will mean those which perform public works projects).

Background

In "The Core Competence of a Corporation," (Harvard Business Review, May 1990) Prahalad and Hamel argue that a corporation is successful when it develops *core competencies* which can be applied to a variety of products and industries. They define a core competency as a skill or skills set which:

1. provides potential access to a wide variety of markets;

2. makes a significant contribution to the perceived customer benefits of the end product; and

3. is difficult for competitors to imitate.

Prahalad and Hamel cite examples such as Sony's ability to miniaturize electronics components (hand-held radios and TV's, camcorders) and Honda's ability to perfect engines and drivetrains (automobiles, motorcycles, generators). In both cases the firms used their core competencies to achieve superiority in current markets and make strategic advances in others. The authors argue that core competencies are typically developed using resources from across the company (and through strategic alliances), and are used to positively impact a wide range of business units and products.

King and de Neufville (1990) employ an Economic Utility analysis to measure the effect which a contractor's need for work and perceived risk of the project impact the contractor's bidding. They found significant evidence that a contractor's need for work results in lower bids, and that perceived risk of the project results in higher bids.

<u>Purpose</u>

The purpose of this thesis is to investigate the importance of core competencies in the competition among general contractors. A specific public works construction market will first be examined for examples of firms which exhibit core competencies. This market will also be analyzed to determine to what extent the competition among the contractors in the market is influenced by the skill levels of the firms within the market. The differences between management and construction skills among the contractors, and on the projects they build, will be estimated. Other factors will be explored which influence the bidding for contracts, and thus influence the competition among the firms. The thesis will conclude with the implications that these findings will have on a large upcoming project in Boston.

Chapter 2: RESEARCH METHOD

As discussed in the introduction, this research project attempts to investigate two related topics:

1. The notion of Core Competencies among general contractors will be investigaged. Do any of the studied firms display Core Competencies, as defined by Prahalad and Hamel? Are these core competencies manifested in their tendencies and successes in bidding for contracts?

2. More generally, the prevalence of skills-based competition among contractors will also be investigated. Specifically, to what extent is a General Contractor's success in winning publicly bid construction contracts determined by the contractor's skill levels vis-a-vis its competitors, and how those skills match the requirements of the project being bid? This project will attempt to determine whether or not contractor's skills vary significantly among several typical elements of a project, and whether a contractor's comparative advantage in some or all of these elements is reflected in their success in bidding on contracts.

Target Study

The "Boston Public Works Construction Market" was chosen as the target study for this project. Twenty-three recent projects were chosen from this market to serve as the basis of study. The projects ranged in value from $3.5MM to $188MM, with an average value of $28MM. Six of the projects were valued at less than $6MM, while three projects were valued higher than $60MM. The selected projects all met the following criteria:

•The projects involved heavy construction work;

•The contracts were awarded by open, competitive bids;

•The projects involved a wide variety of construction work and management activity;

•The contracts were bid on by several contractors, with considerable overlap among the bidding contractors from project to project.

The twenty-three projects involved seven different types of projects:

- •Highway Bridges (1)
- •Earthmoving (1)
- •Sewer Pipelines (5)
- •Water Resevoir (1)
- •Sewage Pump Stations (4)
- •Water Treatment Plants (1)
- •Waste Water Treatment Plants (10)

From this list of projects, the twelve contractors who frequently bid on them were targeted for further study. Of the twelve contractors, nine of them performed the bulk of their work in the greater Boston area, while the remaining three performed work in several areas of the U.S. The three national contractors reported 1990 annual revenues of between $500MM and $1,200MM, while the local contractors' revenues were in the range $20MM to $150MM.

As evidenced by the bidding on the projects, the chosen sample involves a group of contractors with high competitive interaction, where no single contractor appears dominant. The twelve chosen contractors bid on an average of 9.33 of the targeted projects; the contractors won beween zero and four of the targeted projects, and each project was bid on by an average of five of the targeted contractors.

Skills-based Competition

The method of study for analyzing the skills-based competition among the contractors is as follows:

For the targeted projects of study, eight "work types" which were significant parts of most of the projects were identified. These work types involve both actual construction work and management work. The eight work types are:

1.Excavation for Structures
2.Pipelines
3.Tunnelling
4.Mass Concrete
5.Thin Concrete
6.Site/Subcontractor Management

7.Procurement/Shop Drawing Management

8.Mechanical Equipment Installation.

Sixty-six surveys were distributed among various members of the industry. The first part of the survey (Exhibit 6) asked the respondents to rate the skill of each of the target contractors (with whom they were familiar) on their performance in each of the work types listed above. In the case where the General Contractor typically subcontracted out the given work type, the respondent was asked to rate the General Contractor's skill in choosing and managing the subcontractor. The second survey (Exhibit 6) asked the respondents to rate the level of difficulty of each of target projects (with which they were familiar) in each of these same work types.

In an effort to establish a uniform basis for ranking, the surveys defined "most skillful" as a progression of work which would "experience a minimum amount of rework and waste, achieve the fastest schedule, and result in the highest worker productivity". Similarly, "most difficult" was defined as a work type in which most contractors would experience "high rework, schedule delays, and/or low productivity".

The respondents were asked to use the following scales in rating the Contractor Skills and Project Difficulty:

<u>Contractor Skills</u>	<u>Project Difficulty</u>
4=Most Skillful	4=Most Difficult
3=Better than Average	3=Very Difficult
2=Average	2=Average Difficulty
1=Below Average	1=Easier than Most

Targeted respondents were:

•Employees of firms that work as subcontractors (two rebar/steel erectors, one mechanical equipment installer) to the General Contractors, and have worked on some of the projects. Nine surveys were distributed to this group.

•Employees of engineering firms that have performed construction management or inspection services with these contractors on the targeted projects and/or on other projects (four firms targeted). Twenty surveys were distributed to this group.

•Employees of the two state agencies that owned the projects, and who had management or inspection responsibility on the projects. Ten surveys were distributed to this group.

•Employees of the twelve targeted contractors. Twenty-seven surveys were distributed to this group.

Of the 66 surveys sent out, 35 were returned. Many of the surveys were not signed, and thus it is not possible to determine the breakdown of respondents by group.

The actual bidding results of the 23 projects were obtained from the project owners. In each project the low bidder and price was identified, as well as the per cent margin from the low bidder of each of the other contactors' bids.

For each project, a Predicted Outcome of each firm which bid on the project was calculated as follows:

$$\text{Predicted Outcome} = \sum_i \text{Contractor Relative Skill}(i) * \text{Weighting Factor}(i),$$

where i is the index of work types,

$$\text{Contractor Relative Skill}(i) = \frac{\text{Contractor's Skill}(i)}{\text{Ave. of All Bidders' Skill}(i)}, \text{ and}$$

$$\text{Weighting Factor}(i) = \frac{\text{Difficulty of Work Type}(i)}{\text{Average Difficulty Work Type}(i) \text{ over all projects}}$$

The rationale for this method of analysis is as follows: Contractor's Relative Skill measures how skillful a firm is perceived to be in the eight categories vis-a-vis the other bidders--a contractor who outperforms its competitors in one or more work types should have an advantage in the bidding on that project.

The Weighting Factor measures the difficulty of each work type within the project vis-a-vis the market norms. Thus the Weighting Factors are the rewards (or penalties) which a given contractor should experience in the project bidding for the skills (or lack thereof) it possesses in the various work types. A contractor which outperforms its competitors in a set of work types should experience more success in bidding for projects which demand skill in those work types (as measured by difficulty) than in those projects which do not demand skill.

Thus the Predicted Outcome of a firm in bidding a project is calculated such that:

- the Predicted Outcome is higher, the higher the firm's skill vis-a-vis its competitors;
- the Predicted outcome is higher the more closely a firm's high-skill work types match the project's high-difficulty work types.

The Predicted Outcomes of all bidding contractors in all projects are then calculated. The extent to which the Predicted Outcomes are true predictors of a firm's success is measured as follows: for each project, correlations will be run between the bidding firms' Predicted Outcomes and their true Per Cent Margin from Low Bid. A negative correlation is expected--higher Predicted Outcomes should correlate with lower Per Cent Margins.

By normalizing the Predicted Outcomes by both the low bidder and the average bidder on each project, the correlations can also be run for each contractor. Once again, a negative correlation between Predicted Outcome and Margin From Low Bid would indicate that bidding outcomes on these projects are based on relative skills.

Population-wide trends can also be examined: does the correlation work better in some types of jobs than in others? Are differences evident between large projects and smaller ones? Are some contractors consistently bidding in line with, or out of step from, their predicted ranks?

A strong correlation between the firms' calculated Predicted Outcomes and their actual outcomes in bidding for the projects would indicate that a firm's skill level relative to that of its competitors is a major determinant of its ability to win contracts; a weak correlation, on the other hand, would indicate that other factors play a strong role in determining which firm will be most successful in the bidding.

Core Competencies

This research project has also been developed to investigate evidence of Core Competencies among contractors. The Eight Work Types have been identified as the possible candidates for core competencies. This list is not intended as an exhaustive list of all activities which a general contractor performs, nor are these activities necessarily the most likely candidates for core competencies. They are, however, a set of common construction and management activities which general contractors regularly perform.

This study will employ the three criteria for a core competency, as defined by Prahalad and Hamel, in order to determine whether a contractor possesses a core competency. In particular, the extent to which a contractor satisfies the three criteria will be measured, and used to evaluate whether a core competency exists.

Criterion #1

The first core competency criterion, "provides access to a wide variety of markets", can be measured by the extent to which the work types are found in various different types of projects. Of the seven types of projects found in this study, the tunneling activity was present in only two project types: three Sewer Pump Station projects and found in four Mainline Sewer projects. Thus it seems that a firm with strong tunneling skills has access to a rather narrow scope of potential markets, and it is questionnable whether this category could be considered the basis for a core competency.

The mechanical equipment category is present in 16 of the projects, or 70%, which cover five of the seven types of projects studied. Thus a heavy construction contractor could expect to employ its mechanical equipment skills in several different project types. All the other construction categories were virtually 100% represented in the projects, and thus also meet the criterion for "providing access to a wide variety of markets".

The management-oriented work types--procurement/shop drawing management and site/subcontractor management, also provide access to a wide variety of markets. Indeed, a firm which possesses these two skills alone could effectively build any of the projects listed simply by hiring and managing subcontractors and suppliers. Furthermore, any general contractor which subcontracts out any portion of its projects must possess these skills, and thus they both satisfy the core competency criterion.

Criterion #2

It appears difficult to assess to what degree the various contractors conduct the given work types so as to "make a significant contribution to perceived customer benefits". Indeed, the customer (the owner) has specified his needs exactly by way of the plans and specifications. Furthermore, in terms of work put in place, there can be no relative scale of providing benefits to the owner; a completed work segment either satisfies the specifications, or it doesn't, as determined by the impartial judge (the inspector). Therefore, it appears that any construction activity which is present in a project will absolutely contribute to customer benefits, and those which are not present cannot contribute to customer benefits whatsoever.

Nonetheless, the project difficulty survey is being presented as a possible relative scale by which this second core competency criterion can be evaluated. As explained above, the quality and definition of the final product is completely determined by plans and specifications, and the only possible variation in contributing to "perceived customer benefits" rests in the pricing which contractors apply to the work: lower cost provides greater benefit to the owner. It is hypothesized here that difficult work types in projects will create a wider range of pricing by the bidding contractors than easier ones, because wider cost structures could be expected among the contractors. Thus work types which more typically are ranked as high in difficulty are more likely candidates for satisfying this second criterion as a core competency.

The procurement/shop drawing management activity contains a more readily recognized scale for contributing to perceived customer benefits. A firm which diligently researches all possible sourcing for a product may discover higher quality or lower cost versions than its competitors. Construction contracts often contain "Value Engineering" clauses, in which contractors can present less costly methods or products, and the cost savings is shared between owner and contractor.

A firm which provides the equipment and methods as specified by project guidelines has produced the minimum acceptable level, and probably doesn't meet this second core competency criterion. Those firms which effectively research and present alternative, and less costly, plans, on the other hand, will more suceessfully contribute to percieved customer benefits. Thus while the construction activities depend on high level of difficulty in order to contribute to customer benefits, the procurement work type is linked to the contractor's perceived skill in performing this function.

Criterion #3

The third criterion for a core competency, a skill which is difficult for competitors to imitate, will depend closely on the results of the contractor's skills survey. Firms with a reported skill in a work type which is clearly higher than the reported skills of most of the other contractors in the study will be deemed to have satisfied this third criterion for a core competency.

Management Skills vs. Construction Skills

In Chapter 4, the survey responses and the personal interviews will be examined together to evaluate the differences between management skills and construction skills. The implications that management skills have on bidding will be examined. The Deer Island construction projects may provide some added insights into this issue, since these projects are widely believed to be management-intensive. Several "lessons learned" to date on the Deer Island project will be discussed, as well as what these lessons indicate about the upcoming Central Artery construction program.

Other Factors Which Influence Bidding

In Chapter 5, some other factors which influence bidding which are not skills-based will be examined. To gain an industry perspective on these issues, personal interviews were conducted with eighteen industry representatives (contractors, subcontractors, owners, and engineers). The respondents provided opinions as well as individual case studies of other possible influences on bidding. Two major themes were explored:

The Role of Innovative Construction Methods in Bidding: Do firms often win bids because they develop innovative methods which would provide significant cost advantages? Is a firm's ability to innovate related to its skills? What are the risks/rewards of innovation?

Bidding within the context of a larger construction program. The quantitative research examined projects which were part of one large construction program (Deer Island) and one small program (Wellesley Sewer Extension), as well as several individual projects. Industry representatives were surveyed as to the different strategies employed in single project vs. program bidding. The bidding in the two programs will also be examined for possible trends.

Chapter 3: RESULTS OF RESEARCH

Core Competencies

Table XX lists the Reported Skill Levels of the twelve contractors in each of eight work types. An average of 15 respondents rated each of the twelve contractors, with 4 the low number of responses and 25 the high. The mean and standard deviations over all the contractors in each of the worktypes was:

	Mean	Stand. Dev.	Scale
Excavation	2.67	0.45	4=Most Skillful
Pipelines	2.41	0.72	3=Better Than Average
Tunneling	2.04	0.80	2=Average
Mass Concrete	2.82	0.4	1=Below Average
Thin Concrete	2.71	0.46	
Site Mngmt.	2.70	0.50	
Procurement	2.73	0.33	
Mech. Equip.	2.62	0.48	

This table indicates that contractors' skills in construction activities are roughly correlated with the frequency that they are typically called upon to perform this work in their projects: the contractors as a group were ranked highly in the work types which they perform most often (Excavation, Concrete) but received lower scores in the works which are more often considered specialties (Pipelines, Tunneling). The respondents were asked to rank these contractors relative to industry-wide norms, and thus it is not surprising that, as a group, they scored "above average" marks in each of the work categories.

Table XX lists the results of the "Project Difficulty" survey for each of the twenty-three projects. The mean and standard deviation results for each of the work types were as follows:

	Mean	Stand. Dev.	Scale
Excavation	2.25	0.52	4=Most Difficult
Pipelines	2.38	0.79	3=Very Difficult
Tunneling	2.59	0.52	2=Average Difficulty
Mass Concrete	2.06	0.63	1=Easier Than Most
Thin Concrete	1.98	0.58	
Site Mngmt.	2.37	0.47	

Procurement	2.41	0.44
Mech. Equip.	2.56	0.51

The same tendency can be seen regarding project difficulties as regarding contractor skills: the construction work types which contractors performed most frequently (excavation, concrete) were, on average, ranked "easier" than the "specialty" work types (pipelines, tunneling, mechanical equipment).

Excavation, Mass Concrete, and Thin Concrete

These results provide a first insight into the existence of core competencies. Some construction activities are regarded as **commodities**--that is, most firms within the industry possess high levels of skill in those activities which are prevalent in nearly all projects. Thus, in order to be a viable competitor in this market, a firm should possess these skills in-house or create strategic alliances with firms that do. A low percentage of the contractors were reported to typically subcontract out these work items, so it appears that firms typically perform the work themselves. One possible explanation for this low rate of subcontracting is that price competitiveness is lost if the General Contractor applying the subcontractor's markup as well as its own to its bids.

Thus it appears that the Excavation, Mass Concrete, and Thin Concrete work types are not likely candidates for firms' core competencies. Each of these activities satisfies the first criterion: Provide access to a wide variety of markets, since the work types were significant elements of all seven project types investigated. The three work types vary in the degree to which they satisfy the second criterion: Makes significant contribution to perceived customer benefits. Using the difficulty-based measure, as discussed in Ch. 2, the reported average difficulty of the Excavation work type varied between 3.33 and 1.40 among the projects, with a mean of 2.25. Similarly, the concrete items varied between 3.22 and 1.00, with a mean of 2.00. All three work types were present in nearly every project, and thus the only question regarding "contributing to perceived customer benefits" is one of degree, not of whether or not the work types do contribute.

Based on the results of the contractor skills survey, however, it appears that these three work types fail the criterion that a core competency should be "difficult for competitors to imitate". For the excavation rankings, the four highest contractors were rated between 3.0 and 3.3, and the mean for the entire group was 2.67. The mass concrete and thin concrete categories also each had four contractors rated between 3.0 and 3.6, and the group means were 2.8 and 2.7, respectively. Most significantly, the standard deviation of the scores in each of the categories were between 0.45 and 0.46, among the lowest of all the work types. The relatively low standard deviations indicate a small spread among the reported skills of these contractors in these skills. Thus it would appear that the Excavation, Mass Concrete, and Thin Concrete work types fail the core competency criterion that they be difficult for competitors to duplicate.

Pipelines, Tunneling, and Mechanical Equipment

A simple scan of the projects reveals that the specialized construction activities--pipelines, tunneling, and mechanical equipment installation--are not as prevalent in this market as the excavation and the concrete work. However, when they do appear on the projects, they are typically perceived as more difficult than the excavation and concrete items, and are more likely to be subcontracted out based on responses to the Contractor Skills survey. Thus contractors which emphasize these skills in-house may focus on a smaller subset of the market, and will be competing against contractors who employ subcontractors in those work types when pursuing these contracts.

In terms of the first criterion, "Provides access to a wide variety of markets", the tunneling work may be lacking, since it was part of only two of the seven types of projects studied. The mechanical equipment activity was present in four of the seven project types, and the pipeline work was found in all seven of the project types.

Similar to the discussion for the excavation and concrete work types, these three work types all satisfied the second criterion, "makes significant contribution to perceived customer benefits" to some degree. The reported difficulties and their prevalence among the work types indicates that pipelines makes some contribution to most of the project owners, but that the contributions of the tunneling and mechanical equipment activities is stronger on the projects in which they are present (based on their reported difficulties).

In terms of the third criterion, "difficult for competitors to imitate" two of the specialty work types displayed much higher variability among contractors than the commodity work types. The standard deviation of pipelines and tunneling was 0.72 and 0.80, respectively, while none of the other categories had standard deviations greater than 0.50. Three firms scored significantly higher than the rest of the group in both pipelines and tunneling (Contractor D, Contractor F, and Contractor K). These three firms scored between 3.17 and 3.5 in pipelines, where the mean was 2.41, and scored between 2.75 and 2.8 in tunneling, where the mean was 2.04. (The high marks of two national contractors in these categories was used in calculating the averages, but will not be considered significant because of the limited number of responses on which their scores are based.)

The mechanical equipment work type provided less indications of satisfying this third core competency criterion. The mean score in this category was 2.62, with a standard deviation of 0.48. One firm was ranked at 3.5 (based on limited responses), while two others scored 3.0. The firm with the highest rank in this category is also a national contractor, and actually competed for only four of the largest projects in this study. This may put into question to what extent it satisfies the first criterion, "provides access to a wide variety of markets" . Since it is not known to what extent this firm employs its mechanical equipment skills to access other national markets, no further comment can be made as to whether or not its high ranking in this work type is evidence of a core competency.

Site Management and Procurement

The two "management" oriented work types, Site/Subcontractor Management and Procurement/Shop Drawing Management, do not provide any clear indications for core competencies among any of the contractors. Both work types clearly satisfy the first two criteria for core competencies, but both seem to be lacking in the third criterion.

These two work types both "Provide access to a wide variety of markets", since a firm which is highly skilled in these two areas could perform construction projects using only subcontractor work. While this type of project management is more prevalent in building construction than in the heavy construction markets investigated here, survey respondents did indicate two firms which had occasionally managed projects in this manner (Contractor B and Contractor E). The potential does exist, however, for more firms to use this tactic.

These management work types also satisfy the second criterion of "makes significant contribution to perceived customer benefits". The procurement/shop drawing management activity provides contractors with an opportunity to satisfy the owners needs in a variety of means. Equipment specifications, in particular, are often written by naming one or two preferred manufacturers, along with the clause "or approved equal". A firm which diligently researches all possible sourcing for a product may discover higher quality or lower cost versions which the owner had not specified. Construction contracts also often contain "Value Engineering" clauses, in which contractors can present less costly methods or products, and the cost savings is shared between owner and contractor.

Those firms which effectively research and present alternative, and less costly, plans, on the other hand, will more successfully contribute to perceived customer benefits. While such skill was not specifically surveyed, one would expect that if one firm clearly outperformed the others in this capacity, it would be revealed in the skills survey. Similarly, the third criterion, "difficult for competitors to imitate", should be closely linked to the responses in both categories in the reported skills survey.

Over the entire group of contractors, both the "site management" and the "procurement" skills were ranked rather highly (2.7, 2.73) with relatively low standard deviations (0.50 and 0.33). Three firms were ranked between 3.0 and 3.5 in the site category, while two firms were between 3.0 and 3.25 in the procurement category. However, due to the high average marks and low standard deviation, it is unlikely that any of these firms can be considered to have core competencies in these areas, save the national contractor that scored 3.5 on the site management work type. However, this firm's score was based on a limited number of survey respondents, and thus will not be considered as a possible core competency.

Analysis of Core Competencies

Thus in reviewing the results of the surveys for the six construction work-based work types and the two management-based work types, it is noted that three firms potentially display core competencies in pipelines and tunneling. Are these likely to be true core competencies? Why were no additional core competencies identified? These two questions will be taken up in succession.

The three firms that were identified by survey as possibly displaying core competencies in pipelines and tunneling work were highly competitive in all of the projects in which tunneling and pipeline work was ranked as highly difficult. In the four of the five sewer projects in which tunneling and pipelines were major portions of the projects, these firms were the only members of the survey group which bid the projects; furthermore, one of these firms was low bidder on all five of the projects. However, one strong indication that these firms do hold core competencies in these work types is the fact that they were successful in winning the projects against several other bidders (not investigated) who specialized in pipeline and tunneling work.

The firms were also quite competitive in the projects in which pipelines and tunneling constituted a smaller portion of the entire projects. In the four water treatment structures projects in which pipelines or tunneling was ranked as highly difficult, (Projects #1, #2, #13, and #17) the pipelines and tunneling actually constituted less than 25% of the total value of the projects. However, these firms were low bidder in two of the projects, second low bidder in three of the projects, and third low bidder in two of the projects. Of the twelve chances for these firms to bid in the top three, the firms actually captured seven of those twelve positions, while each of the projects were bid on by an average of seven contractors.

Thus it appears that these firms are able to leverage their skills in tunneling and pipelines to compete against contractors who specialize in these two work types and to acquire projects which involve a wide variety of work. These two characteristics indicate that these firms do exhibit core competencies in these work types. The contractors' core competencies were achieved by different means. Contractor K has developed a strong strategic alliance with a strong international tunneling contractor to win two projects which involved soft ground tunneling. The tunneling firm's obvious tunneling capability, and Contractor K's skills in a wide variety of projects, made this a successful alliance. The two firms reportedly agreed to purchase a tunnel boring machine which could be used in succession on both of the tunnels. Contractor D and Contractor F developed their pipeline competencies in the 1970's, when both firms were exclusively pipeline contractors. Contractor F has since diversified much more significantly than Contractor D into other types of work.

Why were no other core competencies identified? It is probably not a coincidence that the two most specialized work types were the only candidates for core competencies. The three firms are known to pursue and win these types of projects far more frequently than the others, and thus a respondent might rate them highly in these categories whether or not they are actually skilled in them.

Furthermore, all of the other work types are fundamental to all the projects; if a firm did hold a core competency in these categories, they would be expected to win nearly every project they bid, and this was not the case (no firm won more than 35% of the projects it bid). If the general contractors did hold other core competencies, they may likely be less apparent to casual observers, and may be located more in separate individuals rather than permeating the entire company.

Evidence of Skills-based Competition

Since the previous analysis turned up very little evidence that contractors possess core competencies in any of the work types identified, differing levels of skill were nonetheless identified among the contractors. Thus a more general question will now be considered: Are the relative skills of the different contractors in these work types associated with the firms' relative successes in bidding for projects?

As described in Chapter 2, correlations were run between contractors' calculated Predicted Outcomes and their Margin From Low Bid on all the projects that each firm bid. A negative correlation between these two variables would indicate evidence of skills-based competition among the contractors, meaning that firms' successes in bidding for contracts are related to their relative skill levels in the several phases of a project. A firm's Predicted Outcome was a simple calculation which had the following characteristics:

•firms which were highly ranked vis-a-vis the other bidders should receive higher Predicted Outcomes; and

•Firms whose highly ranked work types most closely matched the work types which were ranked as most difficult should receive higher Predicted Outcomes.

Project Correlations

Exhibits 1a to 1e tabulate the results of the "Project Difficulty" and "Contractors' Skills" surveys, as well as the bidding results on the projects. The data of the Predicted

Outcome vs. Margin From Low Bid for each individual project are plotted in Exhibits 2a to 2l. The Ordinary Least Squares Regression Line is fitted to each of the data sets, and the correlation coefficients have been calculated as the square root of the R^2 coefficient of the regression. The residual values from the regressions have not been documented--due to the calculation method for the predicted outcomes, it is not expected that the residuals between Predicted Outcome and Margin from Low Bid would be consistent from project to project.

The figures reveal that a Predicted Outcome is not well correlated with Margin From Low Bid for most of the projects. Only two projects had correlation coefficients between -0.5 and -1.0, and only nine other projects even had negative correlation coefficients at all. Thus slightly less than half of the projects displayed any tendency for firms with higher calculated Predicted Outcomes to bid at lower prices. The mean correlation coefficient over the twenty-three projects was 0.04, and the standard deviation of the values was 0.50.

The correlation coefficients of the five largest projects (valued between $39MM and $188MM) were the best correlated with coefficients averaging -0.29, and three of the values more negative than -0.39. The five pipeline projects were poorly correlated, with four of the five more positive than +0.50. The six smallest structures projects (valued up to $8MM) had an average correlation of +0.08, and the seven structures projects of intermediate value ($10MM to $20MM) had correlations which averaged +0.10. The eleven projects with the highest average worktype difficulties had correlations which averaged -0.147, while the twelve projects with lower average difficulties had correlations which averaged +0.266.

A readily apparent trend among these correlations involves projects in which Contractor J was low bidder. Although the firm was ranked lowest in skills in five of the eight work types, the firm was low bidder on three projects: #7, #14, and #15, with total values of over $30MM. The three projects had correlation coefficients which averaged

+0.63, far above the population mean of 0.04. The firm's low predicted outcomes in its winning bids slanted the correlation far to the positive.

The pipeline projects also had high positive correlations in four of the five projects. These four were each bid by only three surveyed firms, and were characterized by wide margins from low bid. The firm with the highest predicted outcome was well off from low bid in each case, resulting in the strong positive correlations.

Contractor Correlations

The data was also analyzed for each contractor to determine whether some contractors' bidding was more closely aligned with its reported skills than others. In order to compare data points from different projects, each firms' Predicted Outcomes were normalized in two different ways:

Normalizing Predicted Outcomes to the Low Bidder: Each Predicted Outcome was taken as a ratio of the firm's score to that of the low bidder to achieve a "Normalized Predicted Outcome". This method implicitly assumes that, from project to project, the low bidders should have consistently high scores. Exhibits 3a to 3g reveal that four correlation coefficients were between -0.40 and -0.50, one was -0.69, and five other coefficients were negative. When plotting the results of all normalized data for all contractors, the correlation coefficient was +0.19.

There did not appear to be any pattern to the correlations: the outcomes among the various subgroups (national contractors, local contractors, low volume, high volume) all appeared random. The findings of the project-based analyses were reflected among the contractors, and those which bid some of the project subsets listed above typically displayed the same tendencies.

Normalizing Predicted Outcomes to the Average Bidder: Each predicted outcome was also normalized by calculating a firm's Relative Predicted Outcome the ratio of its own Predicted Outcome to the average predicted outcome among all the firms which bid the project. The results are shown in Exhibits 4a to 4g. This was done because it is expected that a ratio taken on the average score would more consistently normalize the scores than the single low bidder's score. Using this method, seven of the twelve contractors had negative correlation coefficients, with only three of the contractors having coefficients more negative than -0.375. The correlation between Normalized Predicted Outcome and Margin From Low Bid was +0.063 over all of the contractors.

The results for the contractors between the two methods changed significantly in six of the twelve contractors. Four of the contractors' correlations became more positive, while two became noticeably more negative. Only one of these involved a change in sign. Once again, no significant results were found when the contractors were subdivided by volume or by geographic scope.

Bidders Vs. Non-Bidders

A final method of analysis for skills-based competition was to consider whether differential skill levels affected the contractors' propensity to bid on the projects. Table XX shows, for each project, the Predicted Outcomes of all surveyed contractors. The Predicted Outcomes, in this case, are calculated based on the average reported skill levels of all the contractors in the survey. This analysis controls for size of project differences by excluding, for each project, contractors who have not performed any other project within this survey of comparable size.

The table indicates that in 18 of the 23 projects surveyed, the average Predicted Outcomes of the firms which actually bid the project were higher than the Predicted Outcomes of those firms which did not bid the project (but had bid other projects of similar size). Over all of the projects, the average Predicted Outcome of the group that bid for the contract was 20% higher than that of the group which did not bid. Thus it appears that skills-based competition is limited to determining which firms will actually bid a given contract: those firms whose skills are poorly matched with the requirements of a given project are less likely to submit bids on those projects.

Analysis of Skills-Based Competition

The basic outcome of this analysis is that although there appears to be differences among contractors in their levels of skill in various types of work, these relative skill levels do not significantly coincide with the firms' proximity to winning the bids. The results were analyzed by type of project, average project difficulty, size of project, and annual revenues of contractors. None of these subgroups displayed significant correlations between Predicted Outcome vs. Bid Margin, and thus a more highly skilled firm is not likely to perceive any tendency to bid more closely to the low bid vis-a-vis the other firms who bid on the project. The only significant evidence of skills-based competition was that firms whose skills closely match the project requirements (as determined by difficulties) are more likely to submit bids than other firms. Several factors could be the basis for this lack of evidence of skills-based competition:

Need For Work and Perceived Risk: As discussed in Chapter 1, the influence which a contractor's need for work and perceived risk have on the contractor's bidding has been well documented. The need for work phenomenon, in particular, could negatively influence this study's results in two ways: a low-skilled contractor with high need for work is likely to under bid more highly skilled firms; and a high-skilled contractor with low need for work is likely to bid with very high mark-ups, in order to reap windfall profits in the event that it does win the project. On the other hand, one would expect the perceived-risk influence on a contractor's bidding to move in line with this study: a firm which can apply highly skilled personnel to difficult components of a project should perceive lower risk in that project, and thus bid at lower markups. However, it is out of the scope of this project to actually measure this interaction.

Uniformity of Skills: The surveys did not reveal wide differences in skill levels of the contractors in most of the selected worktypes. Thus, while differences do still appear to exist among contractors, the differences are not strong enough to significantly influence bid outcomes, which nonetheless vary widely. The likely causes of this uniformity of skills is investigated in the next chapter.

Sources of Error: Several problems in the research method and analysis could have negatively impacted the results:

1. Respondents to the questionnaires were typically not familiar with all the projects or all of the contractors. Therefore, a true relative ranking of the contractor skills and project difficulties could not be obtained. In particular, if a respondent ranked only a certain subset of the contractors, that ranking will be valid only on projects which were bid on by firms within that subset. Two naturally selected subsets became apparent: in one subset, respondents were familiar with most or all of the local contractors; another subset was respondents who were familiar with firms that performed work on Deer Island.

2. The Ranking system used a narrow scale of measurement: the scales on both surveys were 1 to 4, where 1 indicated easiest work type or least skillful contractor, and 4 indicated most difficult work type or most skillful contractor. The majority of the responses were 2 or 3, and very few respondents used fractional ranks; thus most of the data did not match Normal Distributions. Furthermore, there may exist finer delineations among skills and difficulties than was reported in the surveys.

3. Respondents may naturally rank contractors according to the type of projects that the firm wins, not the firm's true skill in performing the work. This would most likely occur in situations where the respondent has not witnessed the firm in actual project contexts and therefore bases his/her responses on bidding success. This phenomenon would have most likely occured in the respondents who worked for one of the

general contractors(about 35% of the respondents). The other respondents--members of subcontracting and engineering firms and owner representatives, would not be expected to suffer from this phenomenon.

4. The eight worktypes may not be valid. The eight categories are not all-encompassing nor are they likely to be mutually exclusive. Thus a firm's skill in one area may be counted twice while other firms' relevant skills are ignored. Furthermore, each worktype is granted equal weight in influencing a firm's Predicted Outcome on a given project. The true weights of the worktype difficulties may not be equal (or linear, for that matter), and may vary according to such factors as the prevalence of that worktype on a given project.

Chapter 4: CONSTRUCTION SKILLS VS. MANAGEMENT SKILLS

This research project has attempted to measure the extent to which relative differences in contractors' skills are reflected in contractors' successes in bidding for contracts. The contractors' skills in a variety of construction and management activities have been measured, as well as the level of difficulty of these activities within a group of construction projects. The quantitative analysis described in Chapter 3 indicates that while contractors are perceived to have varying levels of skill in these various functions, the differences do not appear to be correlated with their bidding practices.

In this chapter, the differences in the contractors' skills in the construction and management activities will now be considered. "Construction" activities here are narrowly defined as activities which directly relate to putting constructed work in place, while "management" activities include any coordinating activities which support construction activities, but can be extended to procurement, owner reporting functions, and other administrative functions. Personal interviews conducted with contractors, engineers, subcontractors, and owners who work in this industry will be used as the basis for the analysis.

The contractors' skills survey indicated that the contractors were rather uniformly adept at three of the construction activities: Excavation, Thin concrete, and Mass concrete, while wide variations existed in the two other "specialty" construction worktypes, Tunneling and Pipelines. The three worktypes in which received contractors received highest ratings are the most common of the construction activities, and were found in significant quantities in nearly every project.

The contractors were also generally highly rated in the two "management" worktypes which were surveyed, Site/Subcontractor Management and Procurement/Shop

Drawing Management. The mean scores and the standard deviations in both these categories were nearly identical to those of the three common construction activites listed above. Thus it appears that most industry members surveyed felt that the three basic construction worktypes and the two management activities were all conducted at rather high levels among this group of contractors. This is not a surprising result, of course, since these contractors are regarded as some of the best heavy construction contractors who work in Massachusetts.

While the quantitative survey indicates consistently high management and construction skills, most industry representatives nonetheless indicated that a wide dichotomy of skills exists between these two types of activities. These comments were not directed specifically at this group of contractors or at the work types identified here, but seemed to apply more generally to all heavy construction contractors in the full variety of tasks which they perform. The general consensus among respondents was that most contractors held equal skill levels in performing actual construction activities, but that wide variations did exist in contractors' management abilities. The two types of activities will be considered in succession.

Contractor's Contruction Skills

In considering the firms that were examined in this study as well as other contractors who typically perform medium to large heavy construction projects, virtually all industry representatives indicated that little variation exists in contractors' skill levels in the basic construction activities. The respondents felt that in most instances, the firms would employ similar methods and would experience similar production rates in performing any of a variety of construction activities. There appeared to be three basic reasons why construction skills are uniform among heavy contractors: the skills are fundamental to executing nearly all of the projects, the unskilled firms are usually screened out, and the workers who perform the work have uniform training.

Skills are Common to all the Projects: The most common reason given for this uniformity of construction skills is the fact that the construction activities are common in nearly every project within this industry, and that the fundamental aspects of these activities are identical in nearly all projects. Thus any firm which competes within this market must have a high level of skill in these activities. Although these work skills could be (and sometimes are) subcontracted out, the firm must still possess these skills in-house, because:

•Subcontracting this work often leads to price non-competitiveness, because the mark-up on that work is counted twice (in subcontractor's price and in general contractor's price). The only means for guarding against this mark-up is to have sufficient knowledge of the work type in-house, and use that to negotiate favorable pricing from a subcontractor in need of work.

•The work types are critical to successfully completing most of the projects listed, and the GC must therefore possess that work type skill in-house in order to manage, and indeed replace, the subcontractor (in the case of the subcontractor's failure).

The fact that many firms are successful in winning projects within this market indicates that the basic construction skills required to perform these projects are widely held.

Unskilled Firms are Usually Screened Out: Most respondents felt that a threshold level of projects exists, which rather clearly restricts non-capable firms from competition. The restriction mechanism is made up of several parts: bonding capacity, prequalifications requirements, and firms' self-selecting restrictions.

Bonding: Firms which bid for public works projects must acquire two forms of bonds, or surety. The bid bond is insurance to the project owner that if the contractor is low bidder, it will agree to sign the contract and actually perform the work. The performance and payment bond is insurance to the project owner and to the contractor's suppliers and subcontractors that if the general contractor becomes financially distressed or otherwise cannot complete the project, all of its project obligations will be met. While the two forms of bonds are acquired at different times--all bidding contractors will acquire bid bonds, but only the winning contractor then purchases the performance and payment bond--the bonds are issued on the same criteria, and thus go hand in hand.

In determining whether or not to provide a bond, a surety company evaluates a contractor on three criteria. The firm's net worth and working capital are the financial criteria: contractors are typically thinly capitalized, and a bonding firm evaluates what assets could be liquidated in the event of financial distress. A common "rule of thumb" is that firms are bonded for projects worth up to ten times their working capital. A surety company also evaluates the firm's capabilities in the type of construction being considered. Specifically, the number of similar projects the firm has constructed, and the size of the largest similar project constructed are evaluated in comparison to the project at hand.

Owners' prequalification requirements are also used to screen firms that are allowed to bid. Owners employ various criteria: some examine a firm's net worth (similar to bonding companies); other owners permit firms to bid on projects which are a maximum of twice the size of the largest past similar project the firm has completed. In lieu of the largest similar project, firms can often substitute the total value of similar jobs completed within a twelve month period.

Other screening mechanisms also appear to limit contractors' participation, although these are not full-proof. Several contractors asserted that most non-qualified contractors will realize when a potential project outstrips their construction abilities, and will not bid. This understanding is usually reinforced by an unqualified firm's venture into more complicated projects: those that do survive the heavy financial losses and frustration of a losing project will not quickly venture into that market again. Another screening mechanism appears to be a firm's ability to attract competitve subcontractor bids for the projects: subcontractors will also suffer when working for a non-qualified general contractor, and one representative did acknowledge that this often results in the GC receiving no-competitive quotes, if any at all.

Thus a firm which has not developed a proven track record in this type of work, and thus is perceived to lack the necessary construction skills, will be blocked from the competition by the surety firms, the project owner, and subcontractors.

Uniform Skills Among Workforce: The third reason cited for the uniformity of skills in construction activities was the uniformity of skills among the unionized workers that actually conduct the work. Ten of the twelve contractors in this survey were full signatories to union agreements, and the other two firms used union labor on at least some of their projects. Skills do vary among workers, to be sure, and contractors cited attracting and maintaining competent workers as a common competitive strategy. However, the union trades provide considerable, standardized training to their members, and by hiring out of the union halls the contractors are assured of some standard level of skill.

Where do construction skills reside? Most respondents indicated that the knowledge and skills required to perform the actual cosntruction activities is held from the superintendent level to the foreman level and down to the journeyman level. On smaller projects, one superintendent may have responsibility for all construction activities, while on larger projects the duties are divided (by discipline) among several superintendents. The superintendents are typically either "career men" who have worked their way up from the journeyman/foreman levels, or are engineers by training who have made the leap into operations. Foremen are union members who receive little more hourly pay than journeymen, but who perform more coordination and direction functions and less actual construction work.

The availability of personnel and/or subcontractors who are highly skilled in the construction activities varies with the prevailing economic climate of the industry. The severe downturn in construction activity in Massachusetts since 1989 has clearly made competent superintendents, foremen and journeymen readily available. The size and geographic scope of the firms also influenced their ability to access highly skilled superintendents: one of the national contractors reported regularly conducting wide searches for superintendents in diverse markets, and through national head-hunting firms. The talent searches of the local firms seemed confined to the New England region.

Despite the uniformity of construction skills which most people perceived among the competitors in this industry, the respondents also reported widely varying levels of success among the contractors. While profit data was not available, members of each of the four groups interviewed (project owners, engineering firms, subcontractors, and the contractors themselves) reported that large differences exist in the contractors' abilities to successfully execute projects. Many of the firms have strong reputations: some were highly regarded, while others were the object of strong disparaging comments. The differences in the firms' successes, however, are rooted not in their skills in performing actual construction tasks, but in their abilities to perform the wide range of necessary management functions.

Contractor's Management Skills

Although the surveys indicated little variation among the contractors in terms of their skill in the two management work types, industry representatives nonetheless believed that large differences in management skills are apparent. The management activities which were discussed in interviews were not limited to the Site Management and Procurement functions covered in the surveys. Instead, the industry representatives refered to "management" as all activities which are required in order to allow the workforce to actually perform the construction, from coordinating the work of different crews, to procurement of subcontractors and suppliers, to performing administrative work such as fullfilling reporting requirements to owners.

To successfully build a typical "heavy" construction project, a myriad of information, personnel, activities, and materials must be brought together in a timely and precise manner. After the project has been designed, the principal responsibility for bringing these diverse elements together rests with the General Contractor, and the General Contractor's ability to coordinate these "management" activities is thus the prime determinant of the success of the project.

The management activities seem to encompass the activities which are typically performed by superintendents, project managers, operations managers, and by support staff such as engineers and accountants. The respondents also felt that the management skills which a firm will display on a given project is strictly a function of the personnel who are assigned to the projects, since construction projects are typically run as autonomous units. In other words, management skill is not necessarily consistent throughout a firm but instead varies from member to member.

The "project difficulty" surveys do not indicate significant variations among projects in terms of the level of difficulty of the management activities. Once again, however, industry representatives indicated in interviews that the difficulty of management activities varies widely from project to project. The difficulty of management activity is dependent on project characteristics such as the number of different work activities which require coordination on the project, the ambient site conditions in which the work must be performed, and owner-imposed requirements like scheduling deadlines and reporting requirements.

What Makes a Project Difficult to Manage?

The Deer Island projects provide extreme examples of projects with very difficult management activities. A site visit and a simple review of the general conditions of the project specifications clearly supports this view. Contractors will build nearly $3 Billion worth of projects on the tiny, 210 acre peninsula between 1990 and 1998, and virtually the entire area will be covered by constructed facilities when the project is completed. Contracts totaling more than $1.4 Billion have already been awarded, involving 31 contractors and 1,000 workers. The project presents several challenges to the management capabilities fo the contractors:

High Subcontractor Coordination: the projects involve a wide variety of structures which together will form a massive Waste Water Treatment Facility. Thus most of the projects involve the basic construction activities--excavation and concrete work--as well as large amounts of specialty work--mechanical equipment, piping, electrical work, and most of the typical building trades (roofing, interior finishes, etc.). These projects thus require lengthy procurement and shop drawing review activities, as well as considerable scheduling and coordination of the actual on-site activites. This can be contrasted with projects in which the contractor performs a limited amount of different construction activities, primarily with its own forces--such projects will require far less coordination and procurement.

Limited Work Areas: Each Deer Island contract provides a contractor with a predetermined plot of land to use as an equipment yard, lay down and staging area, and office trailers. Most contractors have refered to the available lay down areas--where materials are stored and partial assembly of constructed works occurs--as severely limited. The MWRA also acknowledges this fact, and has provided each contractor with additional areas in Quincy, MA--a five mile barge ride away! The small work areas also place a premium on subcontractor and worker coordination--most projects require a wide variety of subtrades, and it is the contractor's responsibility for providing each party adequate access to the work. Individual projects located in less-conjested areas will not challenge a general contractor's ability to manage space as much as these projects will.

Limited Access: Indeed, even though Deer Island is a peninsula, all project materials must arrive by barge, a service run by the Authority. The number of truck loads of materials each contractor is allowed to bring by barge is very small, and limited according to the size of the contracts--the firm which is building the $189 MM Primary Digesters is only allowed a maximum of seven truck loads per day. Furthermore, all working and management personnel can only access the island by boat or bus service, both of which leave at periodic, predetermined times. These projects thus require impeccable planning for deliveries and worker access.

Scheduling and Coordination with Other Contractors: Since each individual project is only part of the larger project, each contractor must meet milestones which will facilitate coordination among the projects. Furthermore, the entire project is under a court-ordered timetable for compliance with the federal Clean Water Act. In some cases the contractors are under deadlines to complete phases of the project for tie-in by other projects, while in other cases the contractor must meet milestones to give up control, or assume control, of a given area of the project. Each milestone involves late penalties of between $5,000 and $30,000 per day. The contractors must closely monitor the project schedules in order to avoid these massive penalties.

Stringent Reporting Requirements: The authority has established aggressive minimum requirements for participation of women and minority workers in the project, as well as the subcontracting of certain portions of the work to women and minority owned business enterprises (MBE/WBE). The projects also require detailed safety reporting and a Quality Assurance/Quality Control plan. As the work progresses, the General Contractor must regularly submit to the authority the following reports for itself and for its subcontractors:

- Affirmative Action Plan
- Weekly Worker Utilization Report
- Bi-weekly schedule updates
- the Project Safety Plan
- Quarterly Projected Workforce Table
- Monthly Compliance Report
- Weekly Workforce Statistical Report
- Contr. Monthly Procuremt. Summary

- Certificate of MBE/WBE Completion
- Certificate of MBE/WBE Work Startup
- Documentation of Weekly Safety Meetings
- Quality Assurance/Quality Control Documentation.

The penalties for non-compliance to these reporting requirements include: financial penalties equal to the greater of .01% of the contract price or $5,000, suspension of periodic payments, or suspension of the work.

The contractor which is constructing one of the smallest Deer Island projects provides a good example of the negative affect which these reporting requirements can have on a project. The contractor has successfully built many projects similar to this $300,000 pre-engineered metal building, and yet this project is two months behind schedule and under a stop-work order due to the contractor's inability to acquire and document sufficient MBE participation. All the Deer Island contractors interviewed (four) indicated that the reporting requirements to the project owner and to the consulting engineer greatly exceeds the requirements found on typical heavy construction projects.

Several contractors asserted that these management requirements are evident in all projects, but that in the Deer Island work these skills are vital to successfully conducting the work. In most project situations, most contractors with lower management skills are able to make up for such shortcomings by pushing for more labor productivity. However, without impeccable coordination of on-site personnel and subcontractors, deliveries, space requirements, and authority compliance and reporting, a Deer Island project is doomed to failure.

<u>Are the Management Requirements Usually Reflected in Bidding?</u>

Several industry members indicated that many contractors probably did not correctly estimate the full costs of the additional management activities required. Most construction contracts contain similar scheduling, safety, and MBE reporting requirements, but are not usually enforced to the full extent of the specification. The Deer

Island construction manager, Kaiser Engineers, has enforced the rigid reporting requirements, to the point where contractors felt the reporting requirements were the most challenging part ofthe project. Many of the contractors' managers complained that they "spent all of their management time in meetings with the construction manager." In light of the other management challenges which these projects present, these time-consuming reporting requirements could potentially cause even greater problems for the contractors.

The reporting and coordination requirements of these projects thus requires far more site management personnel than most contractors are accustomed to. While these contractors would typically staff the projects with an approriate amount of superintendents, these projects require full-time schedulers, safety coordinators, QA/QC engineers, purchasing agents, and additional coordination staff. MWRA representatives indicated a noticeable difference between the local and the national contractors in terms of their project staffing. Apparently the larger, national contractors have faced similar management requirements on other large projects, and thus staffed their projects to satisfy their needs from the outset. The smaller local contractors, on the other hand, fell behind schedule in several cases because their projects were initially under-staffed.

Conclusion

Most industry personnel thus believed that the prime determinant of the likely success of a project is the level of management skill which the project requires, and the management capabililties of the personnel which are assigned to the projects. The firms with the best managers are not always most successful in winning the bids, because the costs of such management activities are more difficult to quantify than the costs of the actual construction work. Furthermore, based on past experiences, contractors often do not expect that the full extent of the reporting requirements will be enforced, and thus under-bid these functions.

While industry members who were interviewed that managment capabilities varied widely among contractors, they also indicated that most contractors were reported to have similar levels of skill in performing actual construciton work. Several influences within the market appear to put the construction skills of most of the contractors on par: the skills are common to all of the projects, the firms must have displayed these skills in the past in order to satisfy bonding requirements and owners' prequalification requirements, and the firms employ a uniformly trained source of labor.

Chapter 5: Other Factors Which Influence Bidding

The Role of Innovative Construction Techniques in Bidding

Several owner's representatives and contractors cited a bidding firm's ability to develop innovative construction solutions for the projects to be bid as an occassional factor in producing a victorious bid. Of course, the differential value of the innovative methods cannot be determined absolutely, since the intended methods of the firms that do not win the bid are never revealed. Nonetheless, both the contractors and the owners cited projects in which the contractor employed methods which differed significantly from those that they had envisioned when the job was designed or bid. When asked for examples of innovative methods, the responses seemed to fall into two separate categories: those which were *technically-based* and those which were based on *construction methods*. In both cases, the innovation provided primary benefits in reducing labor costs.

One contractor cited a support of excavation technique involving massive steel plates driven between supporting soldier piles by a backhoe, as opposed to lagging boards hand-placed between the soldier piles by laborers. That solution involved technical understanding--the plates can only be driven into certain soil conditions. Another contractor mentioned a shoring system for elevated concrete slabs which could be moved into position for subsequent pours with very little disasembly as an innovation based on construction methods.

<u>Where do innovative methods originate?</u>

Several contractors cited their use of project managers and other operations-based personnel as a key to generating effective ideas, and indeed, to produce accurate bids at all. "An estimating staff must have links to actual construction...you won't get a good bid if they (the estimators) are working in a vacuum," commented an estimating manager from one of the surveyed firms. Indeed, two of the smaller firms reported employing home-office personnel who split their duty between project management and estimating. One of the largest firms, on the other hand, augments the efforts of its full-time estimating staff with project managers and superintendents who are not currently deployed on projects, including those who are candidates for the projects at hand, if it is won.

Estimating personnel must have accurate, up-to-date cost information for various types of work, to be sure. Generating creative construction solutions, however, apparently involves more than simply using timely cost data. Several contractors felt that developing new methods is basically a process of considering past techniques and combining and/or altering them to fit the task at hand. The construction experience of the estimators is vital to developing possible techniques and effectively evaluating them. The input of several people with operations experience creates a "brainstorming"-like atmosphere which results in better solutions than could have been achieved without the operations perspectives, or if the members of the team had worked individually.

As a young scheduling engineer working for a large contractor, I personally had a similar experience while working on a pre-bid schedule for a large highway tunnel. I was shocked when the project manager who was slated to run the project (if the bid was won) asked me what construction sequence *I would use* to build the job. In retrospect, I now realize that the project manager solicited my opinion on the chance that something I said would provide a slightly different perspective, and would help him build upon the tactics that other members of the estimating team had already developed.

An Example of Innovation Leading to a Winning Bid

The bidding for the Phase 1 Residual Treatment Facilities on Deer Island (August, 1991) is an extreme example of a contractor using innovative construction methods to win a contract. The contract involved constructing several structures which will treat the heavy sludge which settles out of the treatment plant's primary clarifying process:

•six reinforced concrete gravity thickeners, measuring 73 ft. in diameter and 30 ft. high;

•eight steel egg-shaped digesters, 90 ft. in diameter and 140 ft. high, which will anaerobically stabilize the sludge;

•a sludge storage and pumping facility, a gas handling facility, and an odor control and operations facility;

•and large amounts of piping and control equipment.

In relation to the other large Deer Island projects, this contract required relatively little excavation, a moderate amount of concrete work, and massive amounts of pile driving, mechanical piping and structural steel fabrication. The perspective of most of the bidders was that the project would be subcontractor-intensive, as a result of the heavy emphasis on the specialty trades. These specialty trades did not appear to provide any opportunity for comparative bidding advantage: the large and complicated nature of the work would prohibit most contractors from attempting this work themselves (in an effort to seize the subcontractors' mark-ups).

The specialty subcontractors thus held a great deal of power in the bidding: since each subcontractor could expect little, if any, competition, they could price the work with high mark-ups and would easily resist any attempts at "bid shopping" once the contract was bid. Due to the limited number of competitors, there was also no motivation for these subcontractors to quote differing prices to different contractors: regarless of which GC won the contract, each specialty subcontractor faced little competition and thus had a high likelihood of being selected.

The steel digester construction, in particular, was generally believed to be a two-firm competition between Chicago Bridge and Iron Co. and Pittsburgh Des Moines Steel

Co. These were the only two firms in the country that had built this type of digester before (the former has done six previous digester projects, while the latter had done one). Indeed, the contract specifications listed the two firms as the only allowable builders, along with the clause "or approved equal".

For the bidding General Contractors, the competition for the project was thus seemingly reduced to the fifty per cent of the project value which remained after these specialty trades and filed sub-bids were deducted from the total price. The competition was expected to be tight, since the moderate to easy nature of the concrete and the excavation work did not provide comparative advantage to any firm.

However, the winning contractor employed its substantial engineering and management capabilities, as well as its own corporate clout, to alter the competition in its favor. Perini Corporation, of Framingham, MA, discovered two potential alterations to the project which would result in substantial cost savings:

•the firm negotiated with General Dynamics for the construction of the eight massive digesters at one of the firm's shipyards in South Carolina. Thus, instead of having digesters built on Deer Island with union labor, they would instead be built in a controlled shipyard environment, with less-expensive non-union labor, and then floated to Massachusetts by barge. This tactic created an innovative method for delivering the product in place.

•the firm employed its in-house geotechnical/foundation group to re-design much of the project's foundations; specifically, the firm discovered that about half of the proposed steel H-piles could be replaced with far fewer 48" concrete caissons, providing another substantial cost savings. They also designed the landing pier to be built off of Deer Island to receive the barges that would transport the digesters. This innovation was technically-based in the firm's geotechnical capabilities.

A company representative reported that as a risk-hedging tactic, the firm did not even reflect the full value of these cost savings in its bid. However, that company representative as well as several other industry sources pointed to those two innovations as the key to the firm winning the contract at $189 MM, $3 MM below the second bid.

Theoretically, any other firm could have developed either one of these tactics as well, and eliminated Perini's comparative advantage. I point to several of this firm's corporate assets as the reason why it alone developed the plans, and employed them to achieve low bid. First of all, it had design resources available in-house which could be assigned to the foundation re-design in the short amount of time in which the firms had to bid; other firms would need to contract out and wait for the designer to become available; secondly, as a firm with $1.2 billion annual revenues, it has the financial strength to convince a firm like General Dynamics that its idea was feasible, and to invest its own resources in pursuing this opportunity. General Dynamics may not have trusted some of the smaller firms as stable contracting partners.

Third, and most importantly, Perini has the corporate stature, or "clout", required to successfully negotiate these changes with the several impacted parties. The firm had to negotiate with the MWRA as well as the Army Corps of Engineers for the right to build the large landing pier off of the island. Perini also had to refute the claims of several parties that its bid was "non-responsive", and thus should be thrown out:

•the local boilermaker's union, which stood to loose the 100+ new jobs which the on-island construction method would have created. The union attempted to rally public support against Perini for sending these jobs, and the rate payer's tax money, out of state.

•Other general contractors, and the two pre-qualified digester manufacturers, who argued that General Dynamics did not meet the specifications as a competent subcontractor, since it had never built any type of sludge digester before.

In short, Perini was the low bidder on this project for two reasons: it employed its managerial and technical assets required to develop these innovative methods; and its managers believed that it had the corporate clout required to preserve these innovative methods in the face of the strong opposition that they knew it would create.

What are the Risks of Bidding Based on Innovative Methods?

Of course, a contractor faces risks when bidding a job based on an innovative method, since construction methods often require the engineer's or owner's approval prior to implementing it. If the owner does not approve of the new technique, the firm could face losses equal to the amount of the projected savings it entered into the bid.

The bidding for one of the Wellesley Extension Sewer projects provides a clear example of the risks associated with innovative methods. The project involved installing the 60" sewer by standard pipe laying methods, and by tunneling through one area which could not be disturbed.

The contractor which was low bidder based its bidding price in the tunneling portion of the contract on a "pipe-jacking" method to install the tunnel, since the firm had performed similar work for smaller tunnels. Pipe jacking involves shoving consecutive lengths of steel casing forward with high pressure jacks, and then removing the material encountered. Apparently, all the other contractors based their prices on the traditional "liner plates" method of tunneling, where material is first removed, and plates are then set into place to maintain the edges of the tunnel.

As a result, the winning contractor's price was 20% below that of its competitors. During subsequent negotiations with the owner (MWRA) and its engineer, the firm was barred from using the pipe jacking method because of doubts that the pipe jacking could negotiate a proposed curve in the tunnel. Attempts to redesign the tunnel path to make it more conducive to pipe jacking installation was also refuted by the authority, and the contractor was forced to revert to the more costly liner plate method.

Bidding in Large Program Environments

Bidding within the context of large programs or "mega-projects", where several projects of a similar nature come available for bid, provides contractors with opportunities for competitive advantage which are not available in one-time bidding situations. Some of the projects examined in this study were part of two large programs: five consecutive pipe-laying and tunneling projects made up the Wellesley Sewer Extension program, and ten other projects involved the construction of various sewerage treatment structures on Deer Island.

The similarities of the various projects within a program, and the repeat opportunities to win projects that the program provides, are important characteristics which firms can use to develop bidding strategies. Contractors who have worked within both of the above-mentioned programs cited two opportunities for advantages which arise from bidding within programs: the opportunity to acquire additional knowledge about competitors, and the opportunity to acquire additional information about forthcoming projects. The potential for gaining information which will lead to comparative advantage in bidding is determined by the extent to which the conditions of the contracts are similar (e.g. owner's special provisions or geotechnical conditions) and the extent to which the actual work types to be performed are similar.

Acquiring Information About Competitors

By competing within a program environment, firms are able to monitor the bidding tendencies of of others, and are also able to monitor the methods and the successes of the firms that actually win the contract. When the type of work and the anticipated competition on future projects is the same as on past jobs, opportunities theoretically arise for firms to forecast others bids, and use that information to predict others future bids.

For example, in the Wellesley projects, all five contracts involved laying large diameter pipe, building cast-in-place concrete junction chambers, and other special construction like river crossings and tunneling. Each of the first three contracts was won by a separate party, and in carrying out their own projects each firm was able to monitor the progress of their competitors' forces. Indeed, the progress of each contractor's crews was mapped on a daily basis on a wall at the inspecting engineer's main field office, in plain public view. In this extreme example of monitoring one's competitors, anyone could determine rather precisely a contractor's actual costs in the various operations, and the mark-ups the contractors used in their bids.

These pipeline projects also provided strong opportunities for gamesmanship because the bids were submitted under unit price contracts. Under this method of contract, each type of work is bid at a unit cost and multiplied by an anticipated quantity to reach a cost for that work type. These costs are then summed to determine total bid price. Thus, except where bid prices are unbalanced or marked-up at different rates, any firm could evaluate other firms' anticipated costs rather closely.

One of the competing firms' estimating managers commented, "By the time the last contract was bid, we all knew each other's past bidding and actual production. It came down to a question of which contractor was willing to do it for the lowest profit." Other members of that firm, whose bid was in second place by 3.3%, felt that the winning contractor had bid at costs which slightly undercut the second place firm's actual past productivity, rather than bidding at its own anticipated productivity. These members asserted that the tactic resulted in lower, but still positive, profit margins, and allowed the firm to win the project.

The unit price contracts for the Wellesley Sewer projects, and the limited number of work types involved, created strong opportunities for competitive advantage in bidding. However, most public works projects are bid on a lump sum basis, and often involve a wide variety of work types, including subcontract work. The large number of the wait-and-see strategy. As reported previously, each of the first three contracts bid in the first two months of the Wellesley program was won by separate contractors, and in the Deer Island projects, each of the first eight large (over $10 MM) structures projects bid within a ten month period was won by a separate contractor. This pattern may be an indication of the need-for-work phenomenon: each firm, by landing one of these sizable projects, may have neared its capacity and thus submitted high prices to compensate for the lower productivity it would achieve in the subsequent projects. However, instead of a manifestation of the Need-For-Work phenomenon, I attribute this phenomenon to the learning, and thus risk-mitigating, effects which contractors perceive as they perform their first contract within a mega-project.

In bidding, each contractor makes its best-guess estimate of a project's true construction costs, and based on past experience, knows that the true project costs will vary from this estimate by an unknown amount (positive or negative). The firm's managers also understand that a possible reason why it was low bidder on the contract was because it underestimated some future costs. Thus rather than risk winning another project with cost calculations which are too low, in bidding subsequent projects the firm will place higher costs on the work phases with the highest possible variability, and/or will place higher general mark-ups on the bid. The firms are aware that several contracts remain to be bid, and thus are still provided ample opportunity to participate once its true costs are assessed.

This trend seems to be substantiated in the bidding of the eight large Deer Island structures projects. Figure XX shows each winning firm's average margin from victory in the bids subsequent to the one it won, as opposed to its margins in the projects it bid previous to its victorious bid. The per cent contribution which the winning bid will make to each firm's annual volume is also shown.

Of the five contractors who bid on projects before and after the project it won, the Margins From Low Bid of four of those five firms was lower on the pre-winning bids than variables in such bidding would seem to preclude any contractor from predicting competitors upcoming bids based on past bidding/performance. Indeed, two contractors representatives working on Deer Island projects asserted that most contractors will not even consider other contractors' possible bids, except in the case of projects with only one other bidder.

However, contractors did mention another type of information which can be acquired from competitors in program environments: the ability to evaluate the methods and results of the competitors' forces, and of their subcontractors, in various work phases. When working in close proximity, contractors can monitor other firms' productivities (and indeed, often hear of the same "through the grapevine") and can use that knowledge in upcoming bids.

For example, much of the Deer Island work is founded on a deep clay stratum, and a high uncertainty existed among bidding contractors as to the clay's resistance to pile driving. In particular, one firm's field personnel reported that the pile driving work on their project was bid at a rate of eight piles (each 90 ft. long) per crew-day, but that actual production to date is at twenty piles per day. They fully expected that most bids for future projects on the island would reflect the productivity which they achieved.

Does the Timing of Projects Affect Bid Prices?

The bidding for projects within a program appears to be influenced by the timing of the projects. Specifically, each contractor's individual need for work and perceived risk of the project are influenced by the timing of the project, and thus affect their bidding. In evaluating one's competitors, a contractor should consider its opponents' need for work. A contractor with a large pool of idle manpower and equipment will often bid at lower profit margins in order to hold on to talented personnel, and to recoup fixed costs on equipment.

Furthermore, a close examination of the contractors' bidding within the two programs appears to also reflect a risk averse strategy in their bidding which I will call on the post-winning bids. For these five firms, their average pre-win margin was 5.6%, while their post-win margin was 12.7%. When the margins of the other contractors (those who have not won projects, or whose winning projects were the first or last projects they bid) are included, the average pre-win margin becomes 6.6% and the average post-win margin becomes 11.8%. The need for work phenomenon is clearly not influencing the firm's bidding, since for the five firms which had pre- and post-win bids, their winning bids were projected to add 8% to their annual revenues.

I attribute this phenomenon of higher bids after having won a project than before winning one to the firms' waiting for additional information in order to reduce risk. Rather than expose itself to another project which has the same possible estimating flaws, the firm will get a reasonable picture of its true costs within the first year of its project. During that first year, the firm will have performed all the buyouts of subcontracted work and materials, and will most likely have performed substantial portions of several phases of the project. That data can then be used to bid subsequent projects within the program with far less potential error in its pricing. The contractor also understands how many more projects will be bid within the mega-project, and thus will only pursue this wait-and-see strategy if a large quantity of projects remains to be bid.

When asked to characterize the expected future trend of bidding for the Deer Island projects, contractors' and owner's opinions varied widely. Some respondents mentioned that the difficult working conditions provided by the tight project area, the difficulties in bringing equipment and supplies, and the construction manager's stringent administrative reporting requirements would lead most current contractors to forsake bidding on future work, except at high mark-ups. Others stated that the vast availability of national contractors to perform the work will continue to bring in new firms.

My opinion as to which firms will win future contracts depends on what markups the current firms have employed, and how much success they actually attain on current projects. I believe that contractors currently working on the island do still maintain an information advantage over those who are not. These working contractors will have their own true experienced costs to provide information for future bids, and have some "through the grapevine" information of other contractors' experienced costs on other projects. Contractors that have been shut-out, on the other hand, have only bid price information on these contracts.

Current contractors will win repeat contracts only if their experienced costs have come in below bid levels. Under that scenario, the contractors will then bid at lower prices--unit costs are lower, reducing the cost portion of their bids; and risk is reduced as a result of less possible variability in the project's outcome, thus reducing mark-ups. This downward pressure on bids should prevent other contractors from breaking into the future projects, even if they adjust their bids to reflect pricing information on past bids.

However, if current contractors' experience results in cost overruns, their future bids will be higher to reflect that project-specific information. Contractors that were previously shut-out will not have that information, and will price contracts based on the company's historical productivity. This information assymetry will result in a constant supply of new contractors winning contracts on the island.

The adverse economic conditions under which all of these projects have been bid may lead to the latter scenario of many new contractors winning projects. The low mark-ups which many contractors reported applying to their winning bids will inevitably lead some contractors to sustain losses on these projects, since the low contingency values in those markups will not cover all unforeseen problems. Once again, the information assymetry will lead current contractors to bid at higher levels than newcomers.

Chapter 6: CONCLUSION

The findings of this research project provide several insights into the nature of the competition among the general contractors in the public works construction market in Boston. The findings of this report are applicable to the Central Artery/Tunnel construction program which is due to commence in Boston in 1992. The report also has implications for the entire Boston market and other public works construction markets.

Central Artery/Tunnel

This report provides several insights into what contractors can expect in the upcoming Central Artery/Tunnel (CA/T) construction program. This project will replace the current Interstate 93 through downtown Boston with a tunnel, thereby unsnarling the daily traffic jams on this road by widening the road and providing better access at all the on-ramps and off-ramps. The interchanges with I-90 and Route 1, at either ends of the project, will also be rebuilt, and I-90 will be extended to Logan Airport by means of another tunnel through Boston Harbor.

The project, valued at $6 Billion, will be subdivided into sixty contracts, ranging in value from $2MM to $300MM. Although the project involves an entirely different type of structure, the CA/T project will nonetheless have many of the same features of the Deer Island project:

Work Types: The contracts will feature massive amounts of excavation and concrete work. The excavation work will likely be more difficult than in the Deer Island projects, since much of it will be performed in a mining fashion to preserve the surface vehicular traffic. The concrete work will be "thin" concrete, for vent buildings and other smaller structures, and "mass" concrete, since the floors and walls of the tunnel will vary from four to twelve feet thick. High subcontractor coordination will be required, as the specialty trades will be installing tunnel lighting, ventilation, and fire suppression systems.

The contracts which precede the actual construction of the tunnel will involve relocating several large diameter sewer lines as well as the myriad other utlities which currently run in the proposed path of the tunnel. The large diameter sewer work will involve both tunneling and open trench techniques, and will differ from the Wellesley Sewer Extension work only in the space limitations which these projects will cause.

Working Areas and Access: The projects will take place in some of the most conjested areas of downtown Boston, surrounded by high-rise office towers and heavy vehicular and pedestrian traffic. Much of the work will be perormed directly below the existing Central Artery, an elevated, six-lane steel struture which must be kept in operation while the tunnels are built. The tunnel construction will be performed by cut-and-cover methods, but will resemble a mining operation in many cases because teporary surface roadways will be put in place while the underground structure is being built. All of these factors will result in highly restricted laydown and staging areas for the work. The notorious traffic jams which afflict the roads in and around this project will also pose serious challenges to timely deliveries of materials, equipment, and workers.

Scheduling and Inter-project Coordination: These projects will also be under very tight schedules since the Deparment of Public Works will attempt to limit the duration of the negative impact which this work will have on the downtown area. Many projects will likely have adjacent projects ongoing concurrently, and will be subject to intermediate and final milestones, complete with severe penalties for late completion.

Reporting Requirements: This project is also under the direction of a construction manager, in this case Bechtel/Parsons Brinkerhoff. The contractors can expect many of the same extensive reporting requirements in minority worker and MBE/WBE participation, Quality Assurance/Quality Control, and scheduling updates.

What Projections Can Be Made About the Central Artery Project?

The results of the Core Competencies and Skills-Based Competition analyses, as well as some of the qualitative aspects of the competition in heavy construction, provides contractors with several suggestions on how to best prepare to participate in the upcoming Central Artery projects, and provides clues of what can actually be expected in the competition.

Core Competencies

None of the current competitors in the Boston Public Works Construction market appears to display core competencies in the excavation and concrete worktypes. Thus it could be expected that, among this group of contractors, competitionwill be tight, with no single firm holding a dominant position in the main tunnel contracts.
Three firms have displayed core competency-like characteristics in large diameter pipelines and tunneling work. Thus it could be expected that these three contractors will be the leading competitors, and winners, in the utility relocation projects.

Skills-Based Competition

Among contractors which actually bid on a project, there will not appear to be any skills-based differences in their bid prices. The skills of the bidding contractors will often be comparable, and yet bid prices will fluctuate widely. Of all the competitors in the Boston market, however, those whose skills more closely match the requirements of these projects will be much more likely to bid on the projects than those whose skills are not well-tailored.

Construction Skill vs Management Skill

Both sets of skills will be essential for firms to participate in the Central Artery projects. Firms must establish and display competent levels of construction skill in order to receive bonding from surety companies, in order to be prequalified by the owner, and in order to receive competitive bids from subcontractors. For firms whose construction skills do not approach the skill levels currently found in the market, it is probably too late to develop those skills now. Firms whose construction skills are close to market levels can improve their competitive position for the later projects by capturing projects which involve large amounts of excavation and concrete work. The projects to pursue should be as large as their bonding and prequalifications will allow, in order to improve their bonding and prequalifications positions for the future.

Firms who already participate fully in this market (and thus exhibit typical skill levels) can expect most other full competitors to possess similar levels of construction skill. These competitors can still improve their competitive position by attracting and retaining competent superintendents, foreman, and journeymen now; even though skills are now reported to be uniform and readily available among these workers, the simultaneous execution of both the Deer Island and Central Artery projects in the next several years will put a severe strain on the availability of competent workers.

Management skills will be a prime determinant of the ultimate success of the firms that actually win Central Artery contracts. All firms who expect to compete should hire and train the necessary set of purchasing agents, scheduling engineers, QA/QC engineers, and accountants, in order to have these people prepared for the various management challenges which the projects will afford. Firms should also hire project managers and superintendents with proven track records of managing projects with severe space and access limitations, high scheduling and coordination requirements, and large excavation and concrete work. It is imperative to hire these personnel now, to train them on the necessary company and project procedures, so that they will be at full productivity when the project commences.

Other Factors Which Influence Bidding

In preparing bids for the Central Artery contracts, firm should involve project managers and superintendents in the estimating process in order to fully explore the true requirements of the projects. The estimating staffs should also constantly search for innovative methods which will provide their firm with a bidding advantage. The Central Artery contracts will all contain Value Engineering clauses, so that innovative methods will at least be considered by the owner. However, firms should not price contracts according to the full savings of their innovative methods, to hedge against the risk of the owner rejecting their innovations.

The contracts will likely be bid at higher margins than the Deer Island work, since the two large programs will be ongoing concurrently, and most firms will perceive lower need for work pressures. The first several contracts will each likely be one by different contractors, as contractors employ a wait-and-see strategy to assess the true costs of the work.

Firms should gather all available information to assess the true cost structures and successes of the contractors who win projects. In the pipeline projects, firms should be able to calculate the actual costs of working contractors, and may be able to impute future pricing. However, each firm should not price future contracts according to competitors' habits, unless the number of competitors is very small. In the larger projects, firms must monitor working contractors' methods and successes on as many worktypes as possible, in order to infuse as much information into subsequent bids as the working contractors will. This information gathering can make firms more price competitive and can avoid the same future losses that working contractors incurred.

Summary

The findings of this research project are as follows:

Core Competencies: While core competency-like phenomena were found on a limited basis (pipelines and tunneling), there was no wide-spread evidence of core competencies among these firms in the eight worktypes examined. That does not necessarily mean that these firms do not hold core competencies; more likely, it is an indication that the competitive bidding system is structured such that core competencies are not apparent when bidding results are analyzed. Core competencies may have been more apparent if one could have controlled for each firms' need for work influences; furthermore, a closer look at these firms' operating practices may well indicate that core competency-like practices are evident after the firm has won a project.

The eight worktypes could also be improper candidates for core competencies: the eight functions are all very common elements of the firms' operations, and the slow rate of technological innovation in these areas could preclude any one firm from holding a clear competitive advantage. By definition, a firm with core competencies holds a clear advantage over its competitors based on that dimension. However, with these selected worktypes being so fundamental to each firms' operations, and with so many firms actively competing in this market, it is not surprising that more firms did not exhibit core competencies in these worktypes.

Skills-Based Competition: Based on the results of the Contractors' Skills and Project Difficulty surveys, the firms which scored the highest Predicted Outcomes did not have any significant tendency to bid more closely to the low bid on the 23 projects examined. Predicted Outcome was a simple scoring formula which is higher for firms with higher ranked skills, and for firms whose highly ranked skills more closely match the high-difficulty elements of a project. This scoring device could be flawed because it gives equal weight to each of the worktypes on every project, and because the surveys may have been flawed by a narrow ranking scale and other respondent biases.

The Margin from Low Bid variable in this analysis is also subject to several external influences: the firms' bid prices are the only determinants of the winning bidder, and as a result the bidding firms alter their price markups based on need for work. If the firms' actual estimated direct costs were available, they might correlate more closely with Predicted Outcomes, if in fact the firms' cost experiences (which are used in future estimates) are dependent of reported skill levels. However, even the direct cost portion of this analysis could be flawed, in the case where more highly skilled firms are able to better estimate all future costs than less skilled firms.

The only significant finding from the analysis of skills-based competition was in a firm's propensity to bid on a project: of the twenty-three projects examined, the average Predicted Outcome of the firms which bid on the project was higher than the Predicted Outcome of those that did not bid (after controlling for firms' size of project limits). This seems to indicate that firms whose skills clearly do not match the project requirements will not even bid the project, because of the low probability of winning the project at an acceptable price.

Construction Skills Vs. Management Skills: In discussions with several engineers, contractors, subcontractors, and owners, the relative degree and importance of construction and management skills was explored. The consensus among industry members was that the skills of actual construction work do not vary widely among most firms, and that the difficulty of the construction activities on different projects are not the prime determinant of the outcome of the project. Instead, the variation in management skills among contractors is readily apparent, and the extent to which a contractor's management skills matches the management requirements of a given project will likely determine the outcome of the project. The implication for public works contractors is that attracting and training competent managers is critical to the success of the firm.

Other Factors Which Influence Bidding: As a result of the skills-based competition analysis, in which contractor skills did not seem to influence bidding outcomes, several industry members were questioned as to what other factors might influence bidding. Two common themes emerged: first, firms sometimes develop innovative construction methods which provide an advantage in pricing a given job. Secondly, by working in a large program environment, firms are able to acquire new information about upcoming projects based on past similar projects. Both of these effects appear to be random, and cannot be predicted in advance. They can provide strong advantages in bidding, however, and should be considered on every project.

Conclusion

The findings of this report indicate that competition among general contractors in public works construction is not an orderly, or rational, process. The results of the firms' competitive efforts in bidding are not determined by a few overriding forces, nor are they controlled by some notion of relative skillfulness among the contractors. Instead, among the large number of competitors, no firm holds a dominant position and the outcomes of the competition are likely determined by the sum of the firms' innovations, gambles, and errors.

The cause of these seemingly random competitive forces appears to be the fragmented nature of the industry. The mature industry has many competitors, there are virtually no proprietary technologies, and there are low barriers to entry into the industry and between the geographic markets of the industry. The basis for competition is thus reduced from core competencies and relative skills to more basic forces like firms' need for work, perceived risk, and isolated advantages like project-specific innovations and the ability to acquire project information in advance.

REFERENCES

Engineering News Record, (1990). "The ENR Top 400 contractors," Engineering News Record, April 4, 1990.

Kosowatz, John J., (1991). "Harbor Cleanup Builds Momentum,", Engineering News Record, Oct. 21, 1991, pp.28-32.

Macomber, J. D. (1989). "You Can Manage Construction Risks," Harvard Business Review Vol. 67, No. 2, pp. 155-165.

Massachusetts Water Resources Authority (1991). "Boston Harbor Project: Fourth Annual Contractor's Forum," December, 1991.

Massachusetts Department of Public Works (1991). Central Artery/Tunnel Project: Construction Contracts and DBE Briefing," October, 1991.

de Neufville, R. and King, D., "Risk and Need for Work Premiums in Contractor Bidding,"Journal of Construction Engineering and Management, Vol. 117, No. 4, pp. 659-673.

Prahalad, C. K. and Hamel, Gary, (1990). "The Core Competencies of a Corporation," Harvard Business Review, May, 1990, pp. 79-90.

EXHIBIT 1a

"PROJECT DIFFICULTY" SURVEY RESULTS

PROJECT	EXCAVATION	PIPELINES	TUNNEL	MASS CONC	THIN CONC	SITE MGT	PROCURE	MECH EQL	# OF SURVEY
1	3.33	3.00	2.50	3.22	2.78	2.89	2.67	2.78	9
2	3.18	3.07	3.14	2.76	2.38	2.56	2.31	2.19	17
3	2.88	2.82		2.35	2.35	2.31	2.23	2.38	13
4	1.80	1.67		2.05	2.23	2.55	2.90	2.80	11
5	2.43	2.86		1.67	2.00	2.14	2.14	2.14	7
6	2.83	2.33				1.83	1.50		6
7	2.50	2.17		2.30	2.11	2.38	2.30	2.56	10
8	1.71	1.30		2.00	2.10	3.00	3.18	3.14	11
9	2.64	2.40		2.54	2.63	3.00	2.91	3.00	12
10	2.00	2.13		2.00	2.00	2.44	2.69	2.50	9
11	1.80	1.17		2.80	2.60	2.90	2.88	3.13	5
12	1.86	1.25		1.93	2.21	2.86	3.00	3.43	7
13	3.00	2.80	2.50	2.95	2.41	2.95	2.82	2.86	11
14	2.09	3.09		2.10	1.90	2.41	2.41	2.30	11
15	2.00	1.00		2.40	2.40	2.40	2.33		5
16	1.44	2.00		2.41	2.18	1.70	1.78	1.67	11
17	2.67	3.11		2.50	2.28	2.44	2.56	2.56	9
18	2.00	3.25	3.13	1.17	1.00	2.63	2.50		8
19	1.86	3.13	1.60	1.20	1.00	1.50	1.71		8
20	2.00	3.13	2.75	1.20	1.00	2.50	2.50		8
21	2.00	3.13	2.50	1.00	1.00	1.63	2.29		8
22	2.00	3.00		1.25	1.00	1.75	2.14		9
23	1.80	1.00		1.60	2.00	1.80	1.80	1.60	5
AVER.	2.25	2.38	2.59	2.06	1.98	2.37	2.41	2.56	9.13
ST. DE\	0.52	0.79	0.52	0.63	0.58	0.47	0.44	0.51	2.85

4=Most Difficult 2=Average Difficulty 1=Easier Than Most

EXHIBIT 1b

PROJECT WORK TYPE WEIGHT FACTORS

PROJECT	EXCAVATION	PIPELINES	TUNNEL	MASS CONC	THIN CONC	SITE MGT	PROCURE	MECH EQP
1	1.48	1.26	0.97	1.56	1.40	1.22	1.10	1.08
2	1.41	1.29	1.21	1.34	1.20	1.08	0.96	0.85
3	1.28	1.18	0.00	1.14	1.19	0.97	0.92	0.93
4	0.80	0.70	0.00	0.99	1.13	1.07	1.20	1.09
5	1.08	1.20	0.00	0.81	1.01	0.90	0.89	0.84
6	1.26	0.98	0.00	0.00	0.00	0.77	0.62	0.00
7	1.11	0.91	0.00	1.11	1.07	1.00	0.95	1.00
8	0.76	0.55	0.00	0.97	1.06	1.26	1.32	1.22
9	1.17	1.01	0.00	1.23	1.33	1.26	1.20	1.17
10	0.89	0.89	0.00	0.97	1.01	1.03	1.11	0.98
11	0.80	0.49	0.00	1.36	1.31	1.22	1.19	1.22
12	0.82	0.52	0.00	0.93	1.12	1.20	1.24	1.34
13	1.33	1.18	0.97	1.43	1.22	1.25	1.17	1.12
14	0.93	1.30	0.00	1.02	0.96	1.02	1.00	0.90
15	0.89	0.42	0.00	1.16	1.21	1.01	0.97	0.00
16	0.64	0.84	0.00	1.17	1.10	0.72	0.74	0.65
17	1.18	1.31	0.00	1.21	1.15	1.03	1.06	1.00
18	0.89	1.36	1.21	0.57	0.51	1.11	1.04	0.00
19	0.82	1.31	0.62	0.58	0.51	0.63	0.71	0.00
20	0.89	1.31	1.06	0.58	0.51	1.05	1.04	0.00
21	0.89	1.31	0.97	0.48	0.51	0.69	0.95	0.00
22	0.89	1.26	0.00	0.61	0.51	0.74	0.89	0.00
23	0.80	0.42	0.00	0.78	1.01	0.76	0.75	0.62

EXHIBIT 1c

CONTRACTORS' REPORTED SKILLS

WORK TYPES

CONTRACTOR	EXCAVATION	PIPELINES	TUNNELLING	MASS CONC	THIN CONC	SITE MNGMT	SHOP DWG MGT	MECH EQL	# OF SURVEY
A	2.66	1.94	1.60	2.75	2.47	2.71	2.86	3.00	19
B	2.08	1.75	1.00	2.71	2.61	2.73	2.69	2.85	14
C	2.72	2.18	2.00	2.60	2.23	2.46	2.80	1.86	18
D	3.00	3.50	2.80	2.36	2.38	2.50	2.56	2.68	18
E	2.13	1.50	1.00	2.60	2.60	2.67	2.63	2.33	10
F	3.12	3.42	2.75	2.95	2.73	2.48	2.52	2.21	25
G	2.75	3.00	3.00	3.63	3.63	3.00	3.00	3.00	4
H	2.70	2.11	2.00	3.27	3.17	3.00	2.89	2.75	12
I	3.00	2.33	2.50	3.00	3.00	3.50	3.25	3.50	4
J	1.89	1.63	1.00	1.93	1.94	1.47	1.94	2.00	19
K	3.34	3.17	2.81	3.26	3.05	3.17	2.94	2.67	19
L	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	1 *
AVERAGES	2.67	2.41	2.04	2.82	2.71	2.70	2.73	2.62	14.73
STAND. DEV	0.45	0.719	0.803	0.452	0.46	0.502	0.331	0.476	

SCALE: 4=MOST SKILLFUL
3=BETTER THAN AVERAGE
2=AVERAGE
1=BELOW AVERAGE

* = WRITER ESTIMATED

EXHIBIT 1d

CONTRACTORS' PREDICTED SCORES

PROJECTS \ CONTRACTORS	A	B	C	D	E	F	G	H	I	J	K	L
1						9.78		9.68			10.76	
2			8.32	9.67		9.91	11.03	9.57		6.01	10.82	
3	7.10			7.37		7.59					8.41	
4	7.15	6.82		7.16	6.45	7.32						
5			6.28	7.18		7.32				4.78	8.09	
6	3.25		3.28			3.85					4.14	
7	7.36	6.97	6.72	7.54		7.74				5.12	8.62	
8						6.42			7.61		7.32	7.20
9	7.87						9.44		9.25	5.47	9.24	8.98
10	7.16	6.80			6.42	7.54				4.98	8.40	
11	6.79						8.06	7.38	7.97		7.76	7.59
12									7.40		7.02	7.13
13	8.77	8.05			7.64	9.86	11.03	9.63	10.56		10.81	10.59
14			6.75	7.72	6.55	7.88				5.12	8.70	
15	5.75		5.50			6.14				3.99	6.90	
16	5.71	5.47	5.28	5.91	5.18	6.16		6.31			6.81	
17				8.81		9.05				5.96		
18			5.85	6.86		6.99		6.38			7.53	
19				5.00		5.17					5.54	
20				6.20		6.35					6.90	
21				5.60		5.74					6.17	
22				4.67		4.85					5.28	
23	5.24			5.22	4.78	5.42						

EXHIBIT 1e

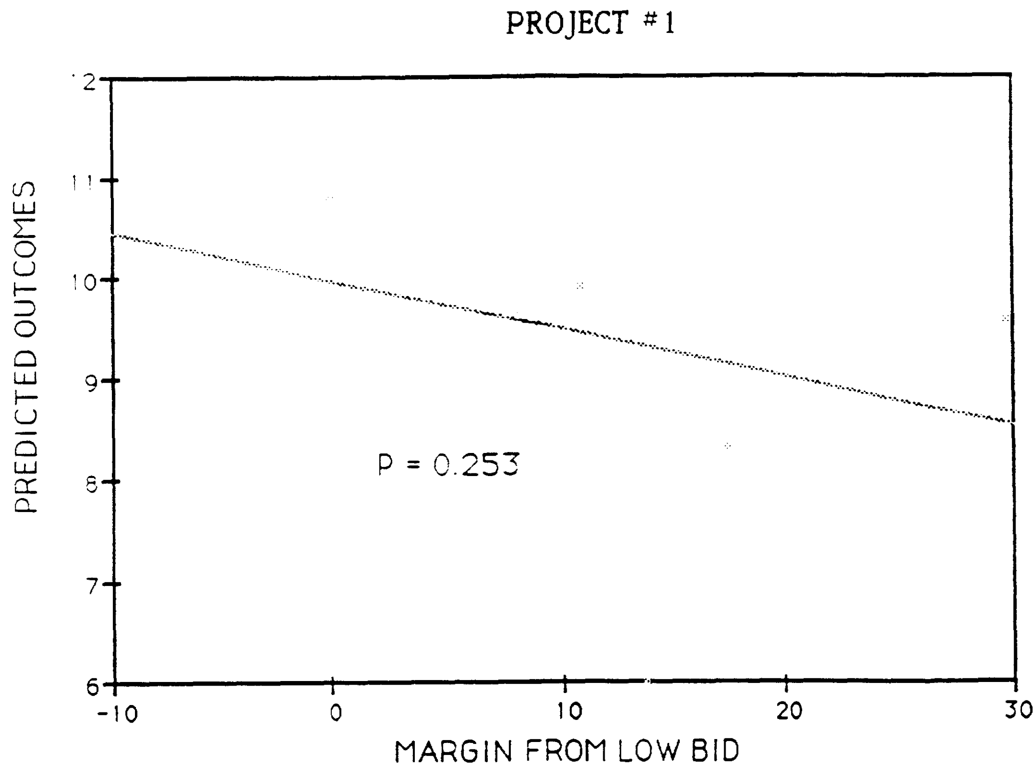
PER CENT MARGIN FROM LOW BID

PROJECTS	CONTRACTORS A	B	C	D	E	F	G	H	I	J	K	L	M	#BID	2ND BID
1						18.5		0			3.6		11.1	3	3.6
2			17.4	8.2		10.8	13.6	29.7		13.6	0		15.6	7	8.2
3	22.9			0		14.5					13.3		16.9	4	13.3
4	0	1.6		7.7	0.4	9.8							4.88	5	0.4
5			0	44.8		4.9				24.5	10.7		21.2	5	4.9
6	37.5		0			6.3					24.1		22.6	4	6.3
7	20	2.2	11.1	33		20				0	9.7		16	7	2.2
8						2.9			3.8		0	5.2	3.97	4	2.9
9	0						13.6		2.3	13.6	3.9	3	7.28	6	2.3
10	10	0.2			14.8	5.8				10.8	18.6		12	6	0.2
11	2.5						0	2.5	23.6		0.5	9.7	7.76	6	0.5
12									0		2.3	2.9	2.6	3	2.3
13	21	10			12.3	6.2	6.1	21	14.2		1.4	0	11.5	9	1.4
14			3.6	33	26	13.5				0	19.1		19	6	3.6
15	9.8		21.3			14.7				0	21.8		16.9	5	9.8
16	10.3	25.8	32.5	34.6	9.4	0		9.3			19.3		20.2	8	9.3
17				15.5		0				6.6			11.1	3	6.6
18			7.7	21.9		7.2		8.2			0		11.3	5	7.2
19				20.4		0					30.4		25.4	3	20.4
20				0		24.5					23.2		23.9	3	23.2
21				0		17.8					22.7		20.3	3	27.8
22				3.3		0					14.8		9.05	3	3.3
23	5.7			0	19.7	11.3							12.2	4	5.7
TOTALS	11	5	8	14	6	20	4	6	5	8	20	5		112	

14.0 '=AVE MARG FR. LOW   AVE # OF PROJECTS BID= 9.33

2ND BID AVE MARGIN= 7.19   AVE # BIDDERS/PROJ= 4.87

EXHIBIT 2a: **Predicted Outcomes vs. Margin From Low Bid Correlations for Projects**



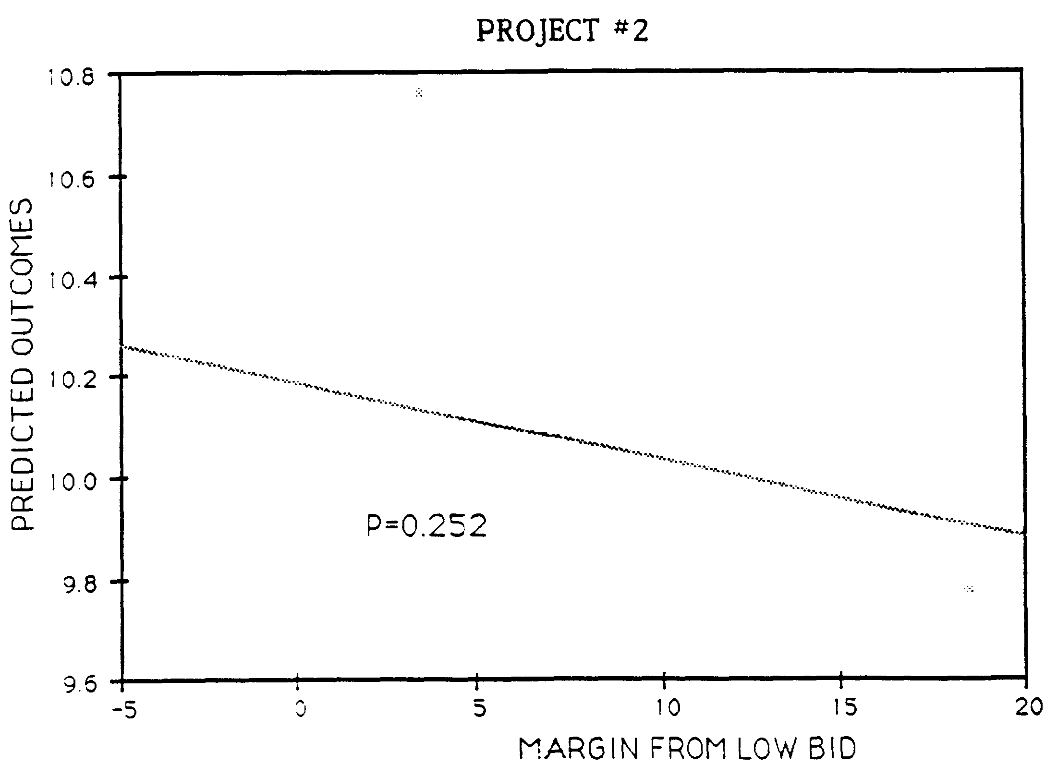
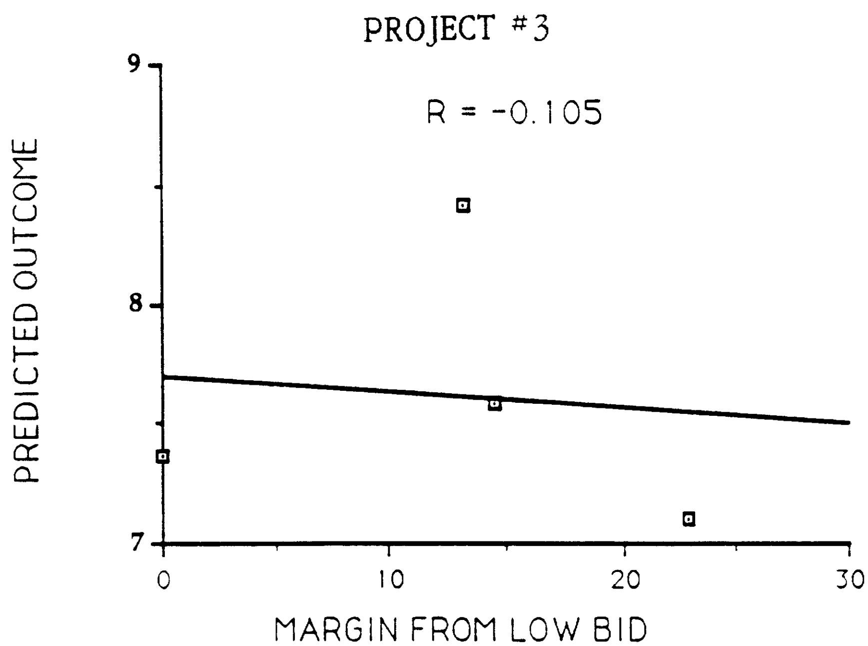


EXHIBIT 2b


PROJECT #3
R = -0.105
PREDICTED OUTCOME
9
8
7
0
10
20
30
MARGIN FROM LOW BID

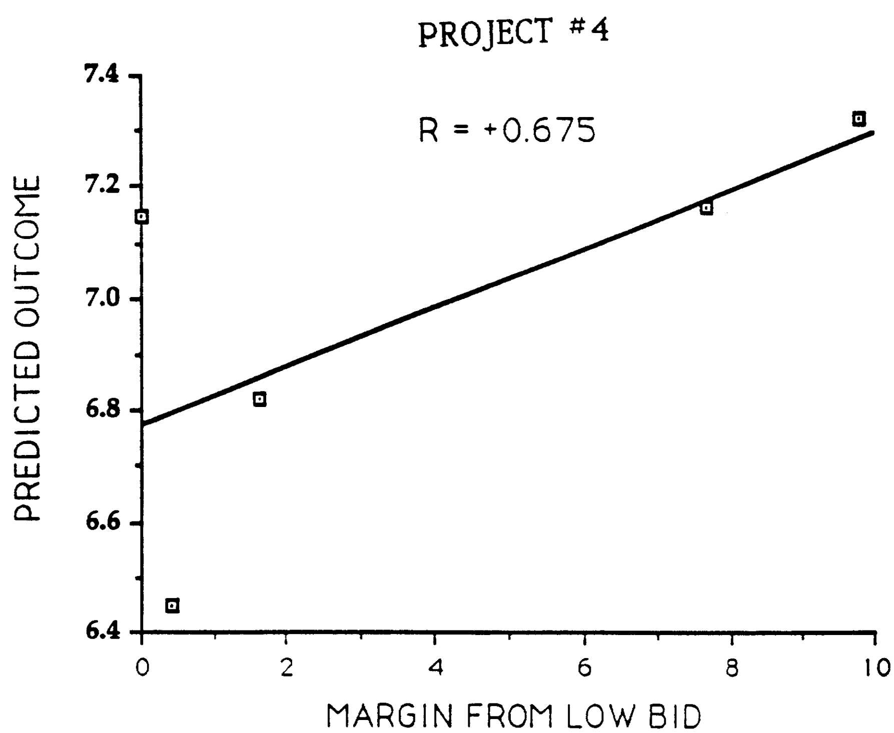
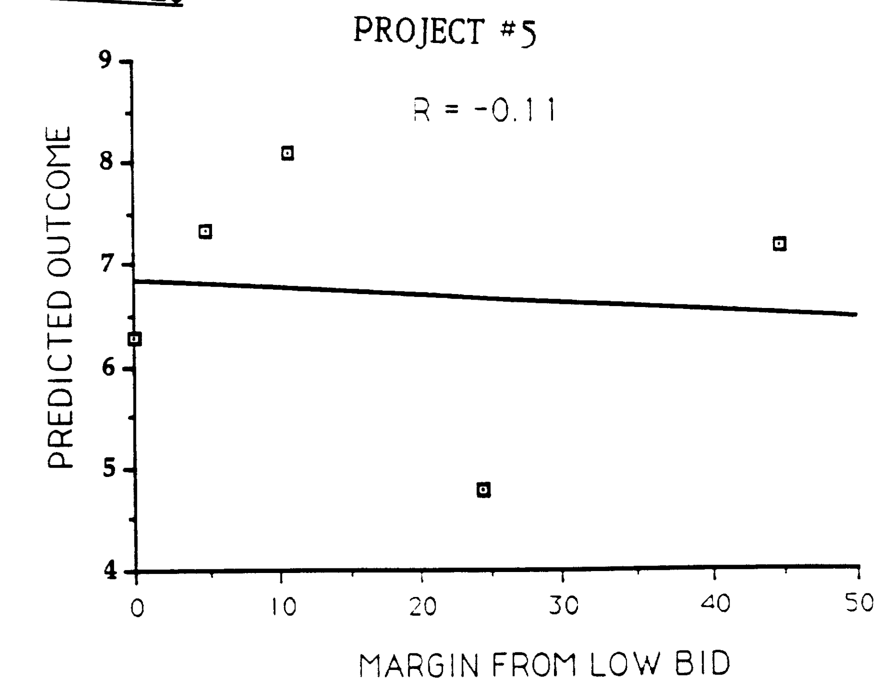

PROJECT #4
R = +0.675
PREDICTED OUTCOME
7.4
7.2
7.0
6.8
6.6
6.4
0
2
4
6
8
10
MARGIN FROM LOW BID

EXHIBIT 2c


PROJECT #5
R = -0.11
PREDICTED OUTCOME
9
8
7
6
5
4
0
10
20
30
40
50
MARGIN FROM LOW BID

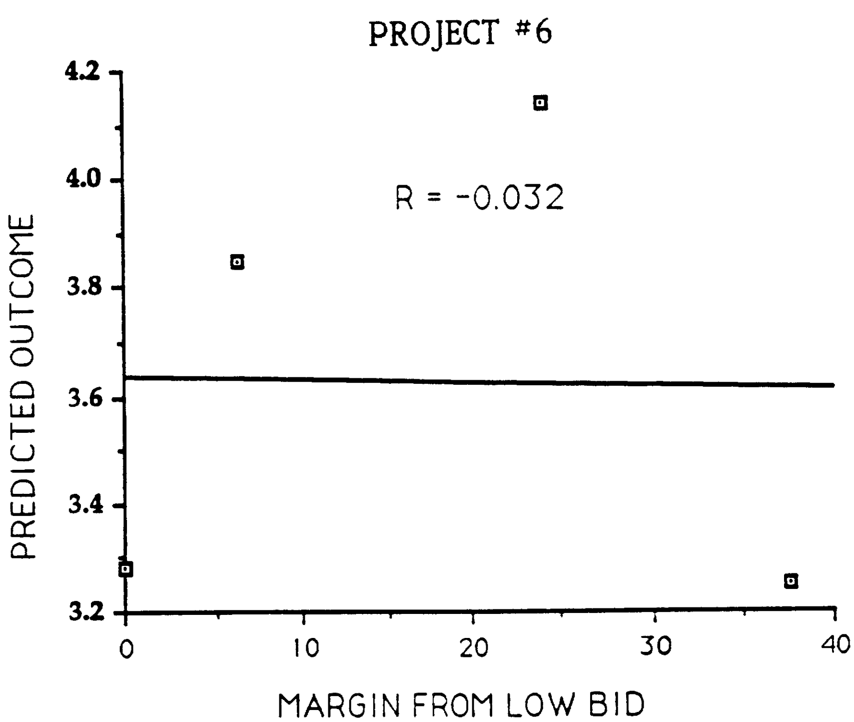
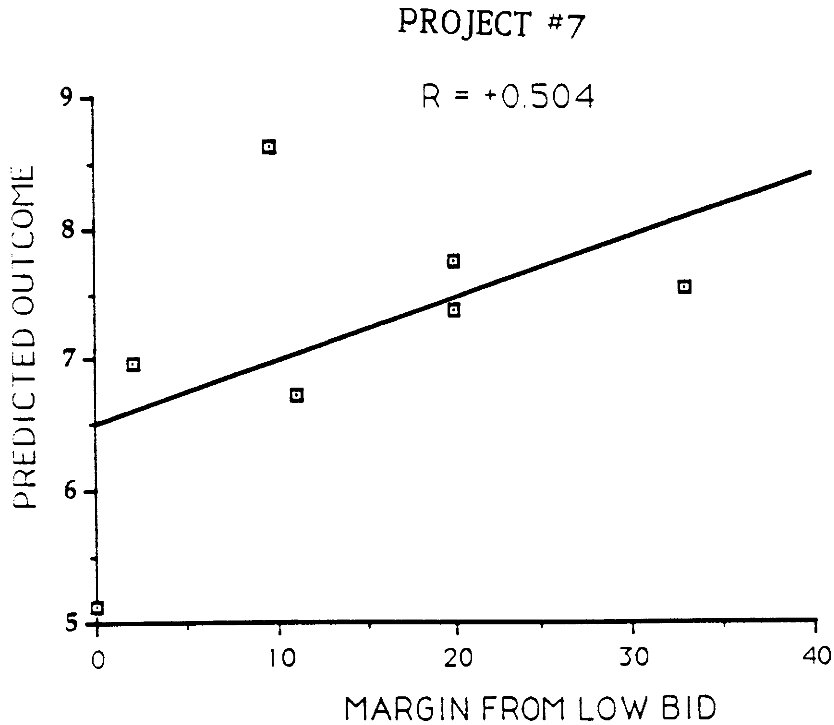

PROJECT #6
R = -0.032
PREDICTED OUTCOME
4.2
4.0
3.8
3.6
3.4
3.2
0
10
20
30
40
MARGIN FROM LOW BID

EXHIBIT 2d


PROJECT #7
R = +0.504
PREDICTED OUTCOME
9
8
7
6
5
0
10
20
30
40
MARGIN FROM LOW BID

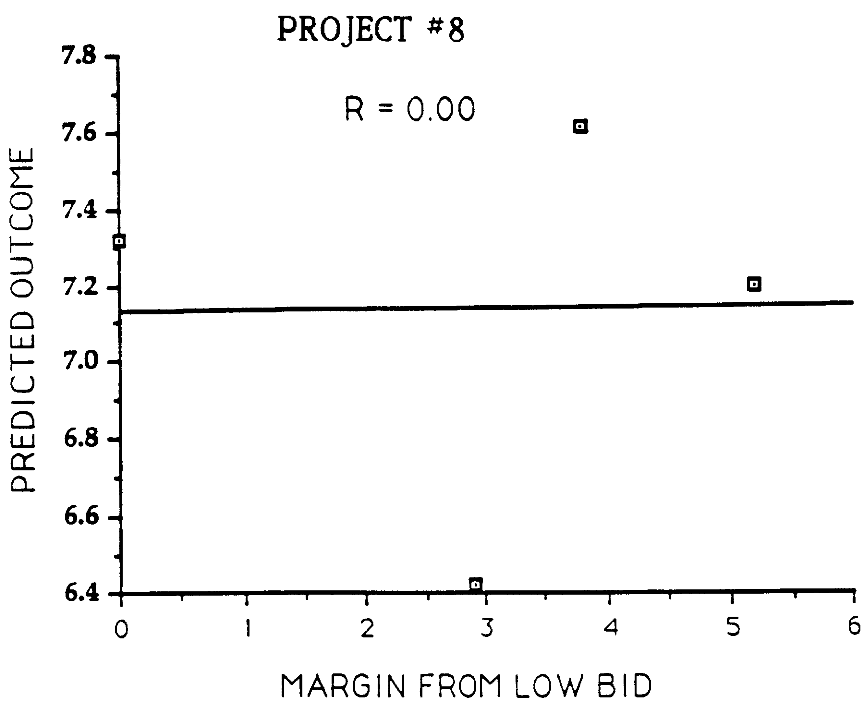
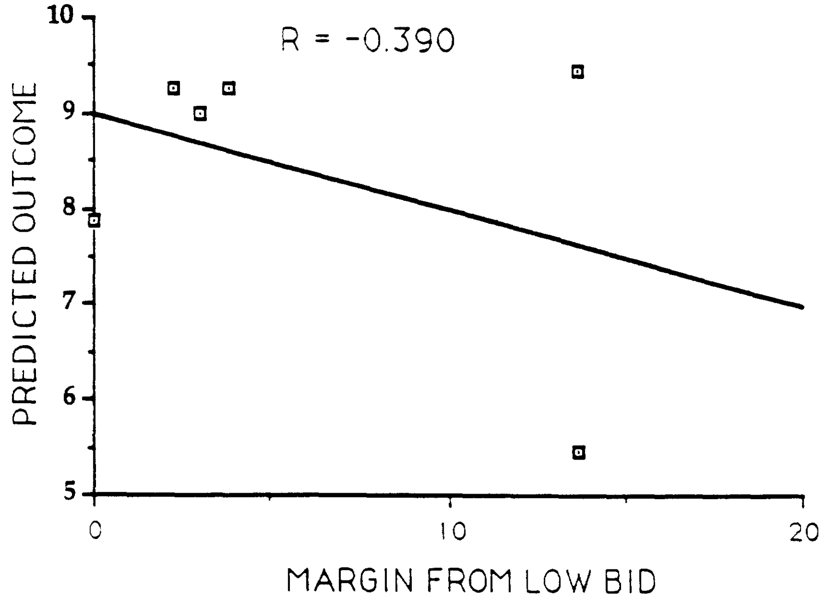
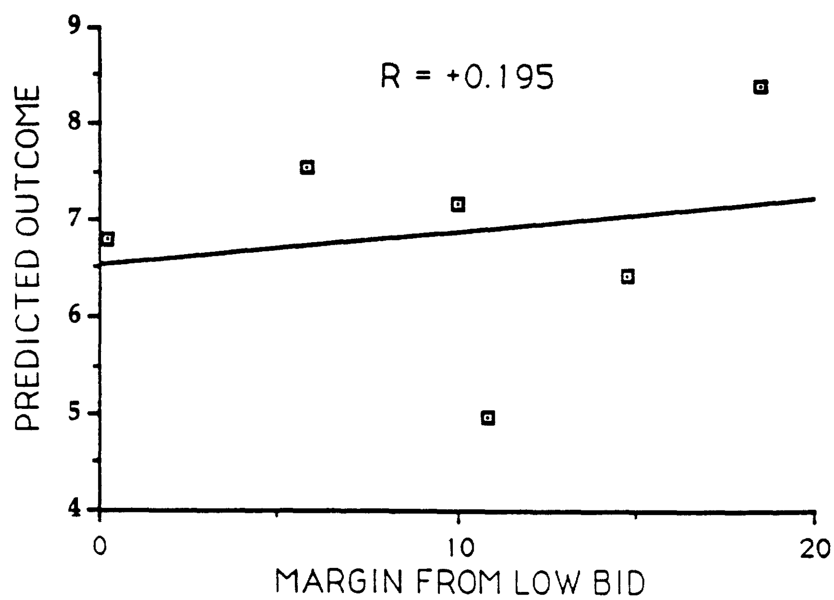

PROJECT #8
R = 0.00
PREDICTED OUTCOME
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
0
1
2
3
4
5
6
MARGIN FROM LOW BID

EXHIBIT 2e

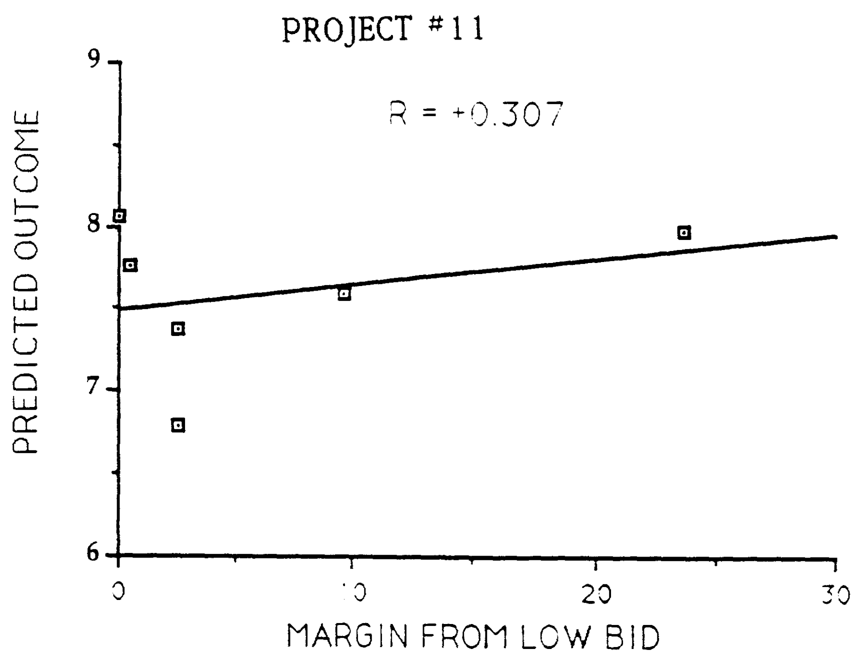
PROJECT #9



PROJECT #10



<u>EXHIBIT 2f</u>



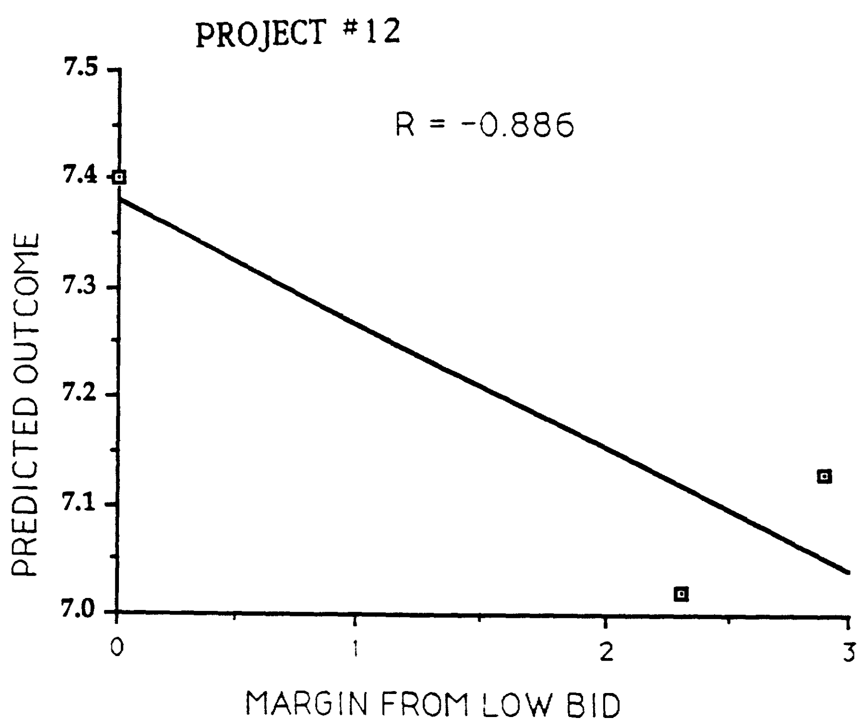
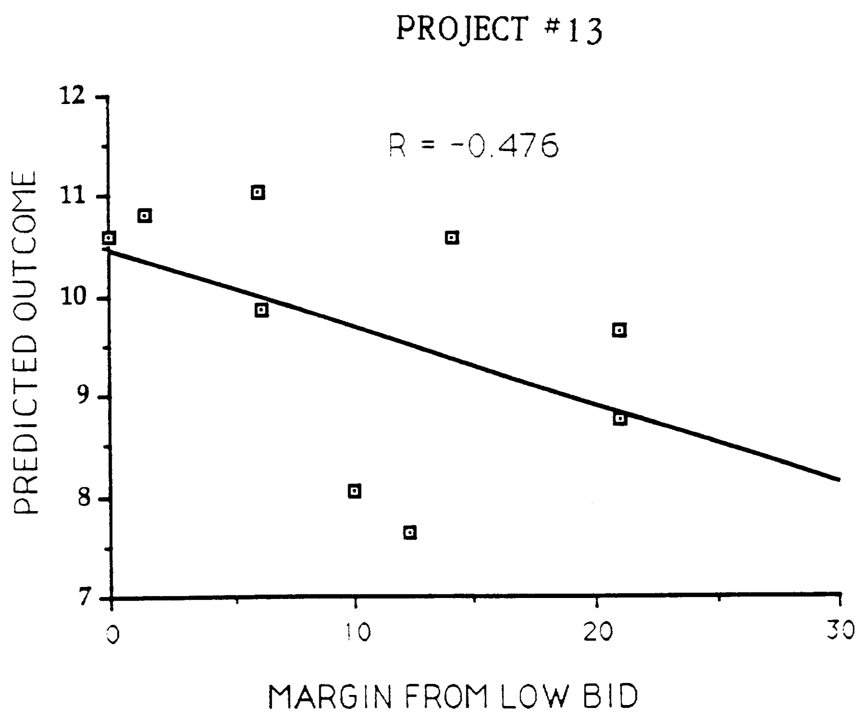


EXHIBIT 2g


PROJECT #13
R = -0.476
PREDICTED OUTCOME
MARGIN FROM LOW BID
12
11
10
9
8
7
0
10
20
30

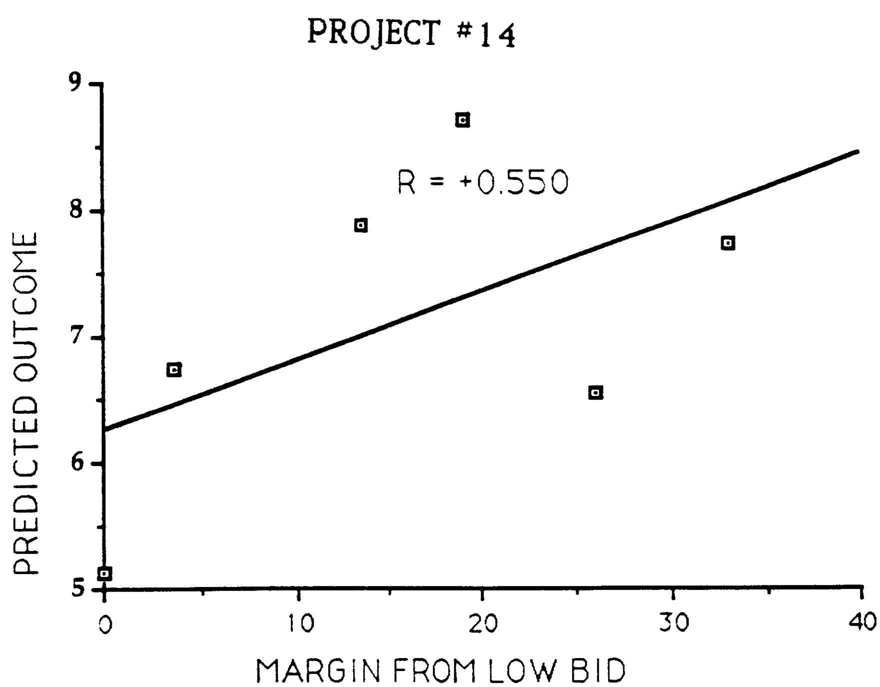
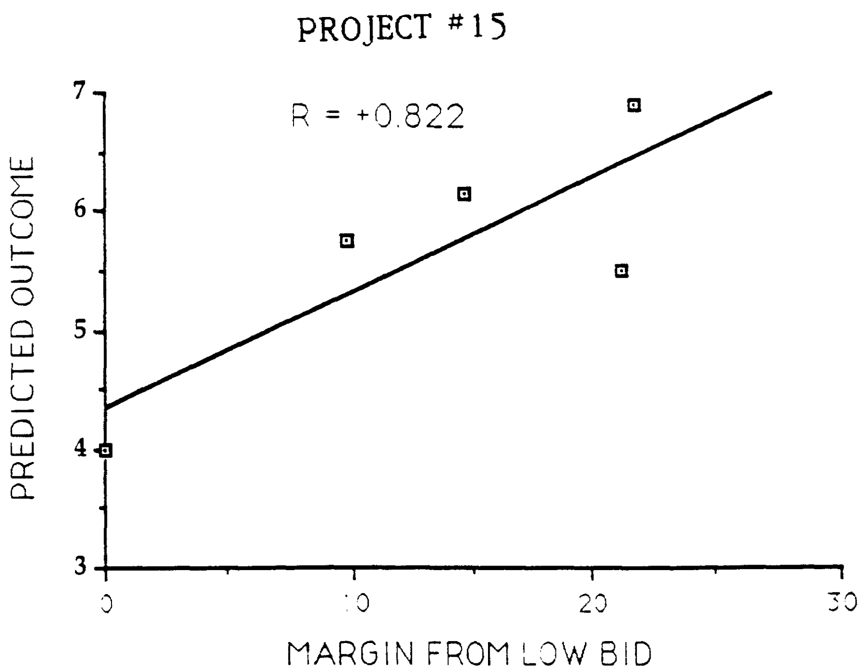
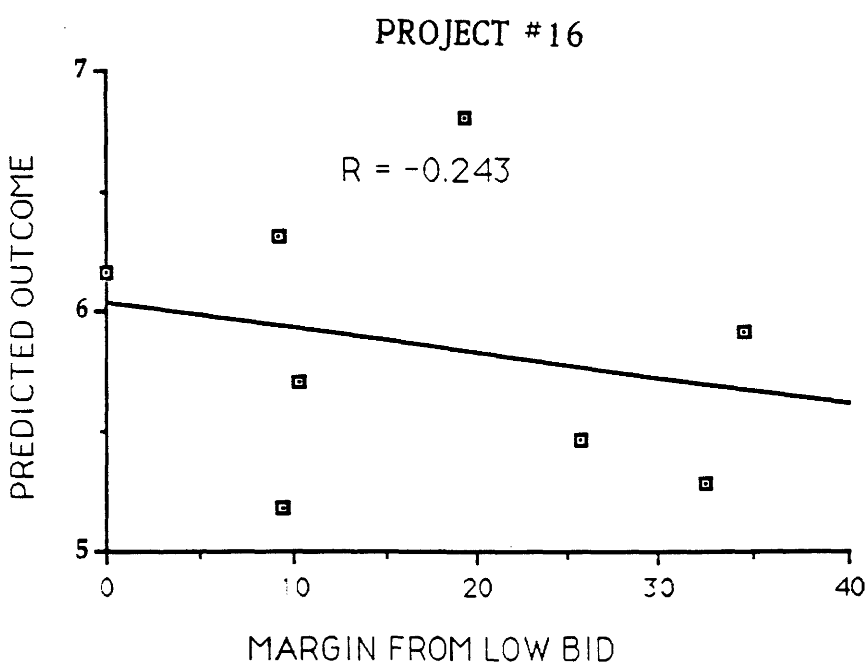

PROJECT #14
R = +0.550
PREDICTED OUTCOME
MARGIN FROM LOW BID
9
8
7
6
5
0
10
20
30
40

EXHIBIT 2h

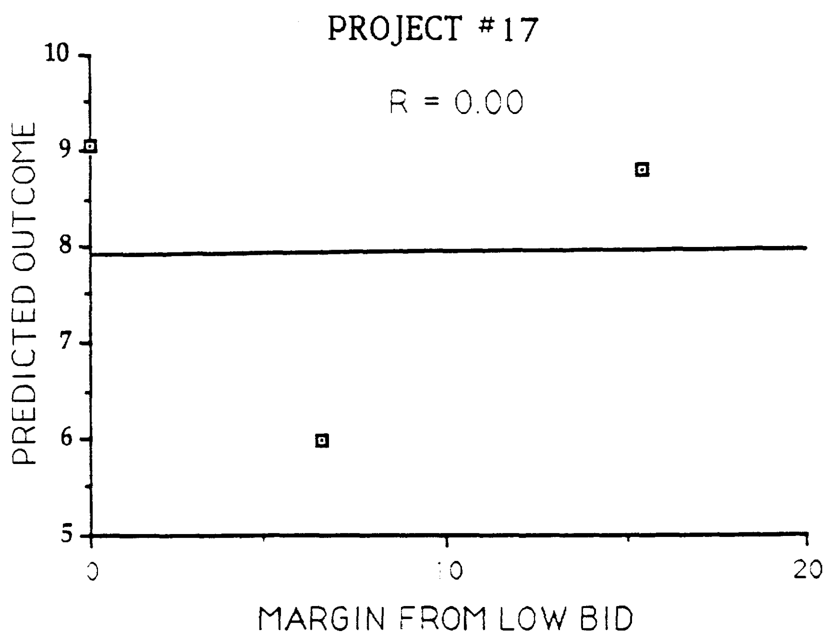


PROJECT #15
R = +0.822
PREDICTED OUTCOME
7
6
5
4
3
0
10
20
30
MARGIN FROM LOW BID

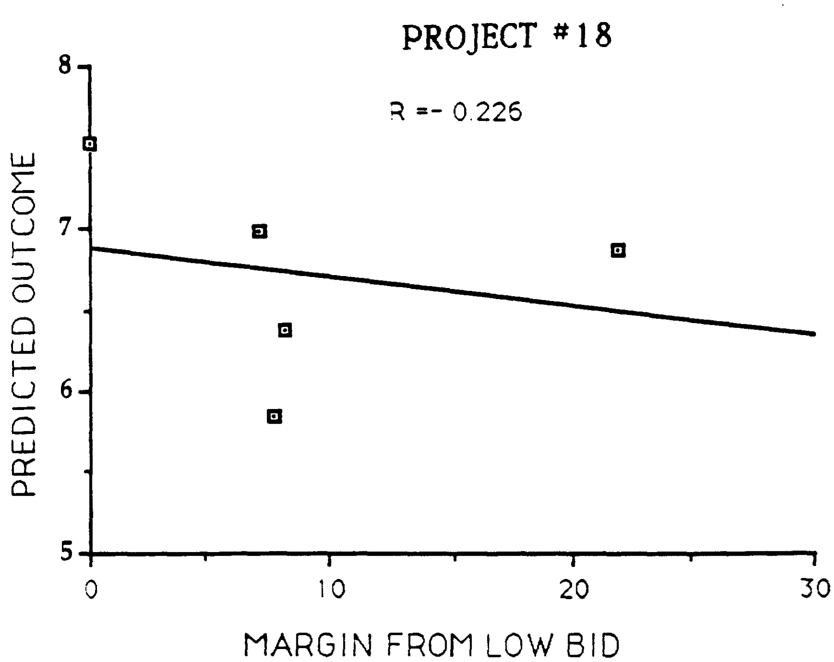


PROJECT #16
R = -0.243
PREDICTED OUTCOME
7
6
5
0
10
20
30
40
MARGIN FROM LOW BID

EXHIBIT 2i

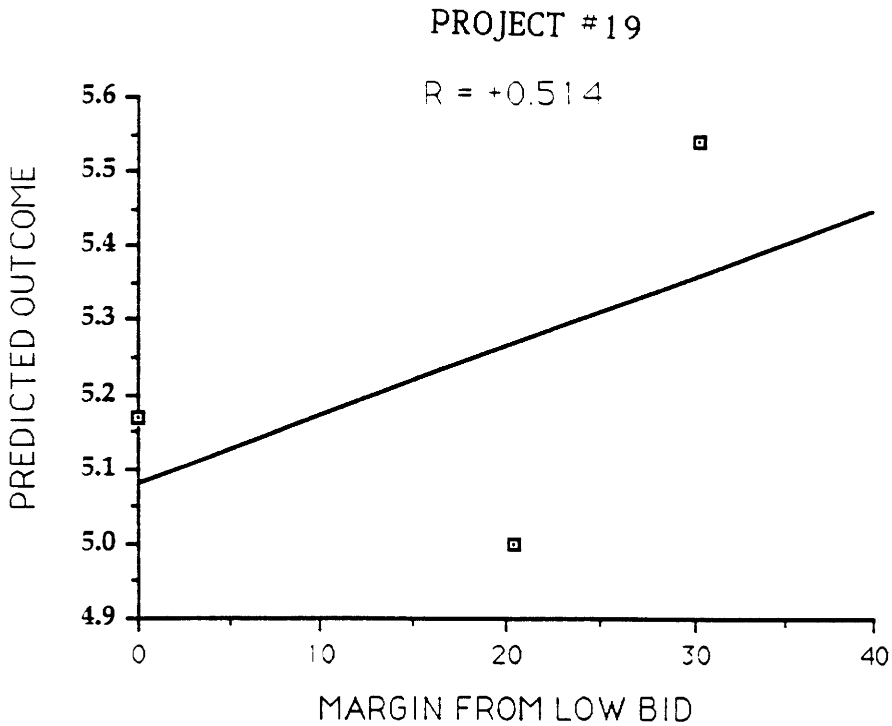


PROJECT #17
R = 0.00
PREDICTED OUTCOME
10
9
8
7
6
5
0
10
20
MARGIN FROM LOW BID



PROJECT #18
R =- 0.226
PREDICTED OUTCOME
8
7
6
5
0
10
20
30
MARGIN FROM LOW BID

EXHIBIT 2j


PROJECT #19
R = +0.514
PREDICTED OUTCOME
5.6
5.5
5.4
5.3
5.2
5.1
5.0
4.9
0
10
20
30
40
MARGIN FROM LOW BID

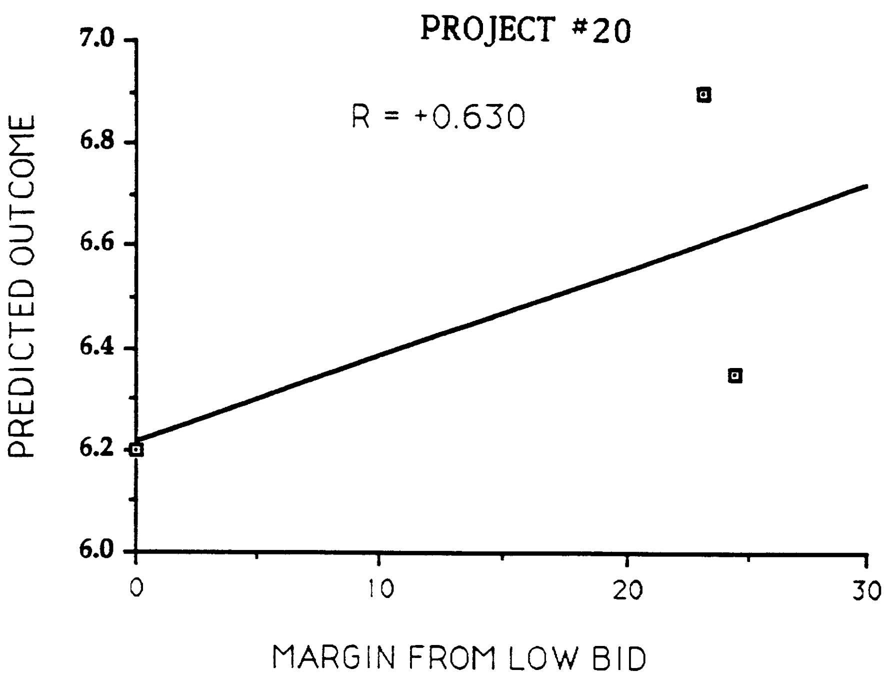
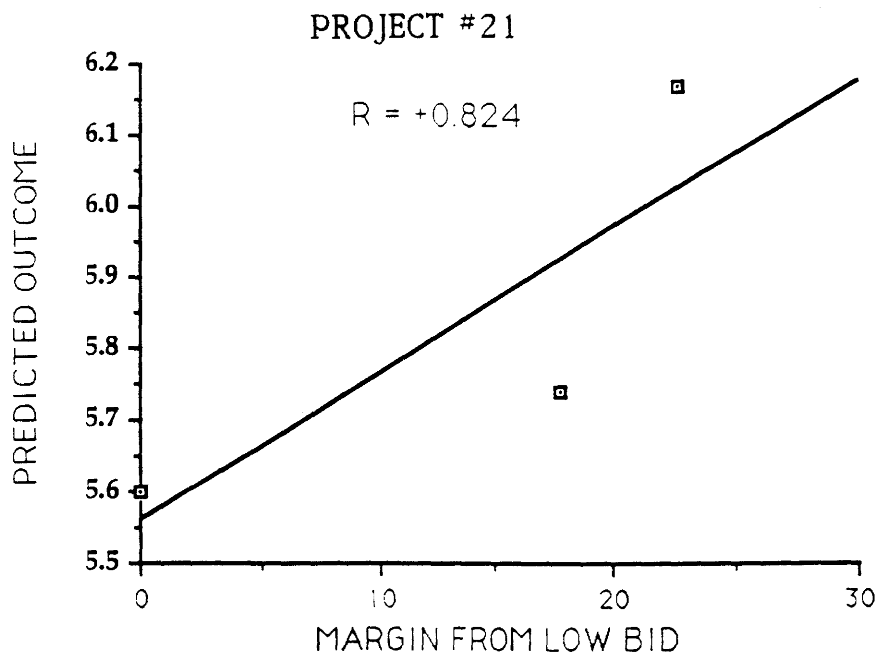

PROJECT #20
R = +0.630
PREDICTED OUTCOME
7.0
6.8
6.6
6.4
6.2
6.0
0
10
20
30
MARGIN FROM LOW BID

EXHIBIT 2k


PROJECT #21
R = +0.824
PREDICTED OUTCOME
6.2
6.1
6.0
5.9
5.8
5.7
5.6
5.5
0
10
20
30
MARGIN FROM LOW BID

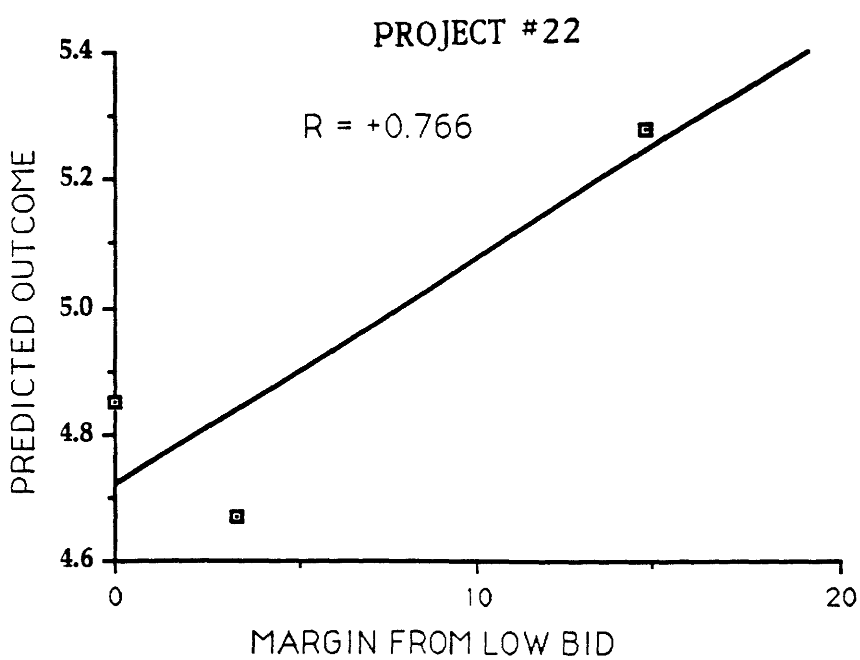

PROJECT #22
R = +0.766
PREDICTED OUTCOME
5.4
5.2
5.0
4.8
4.6
0
10
20
MARGIN FROM LOW BID

EXHIBIT 21

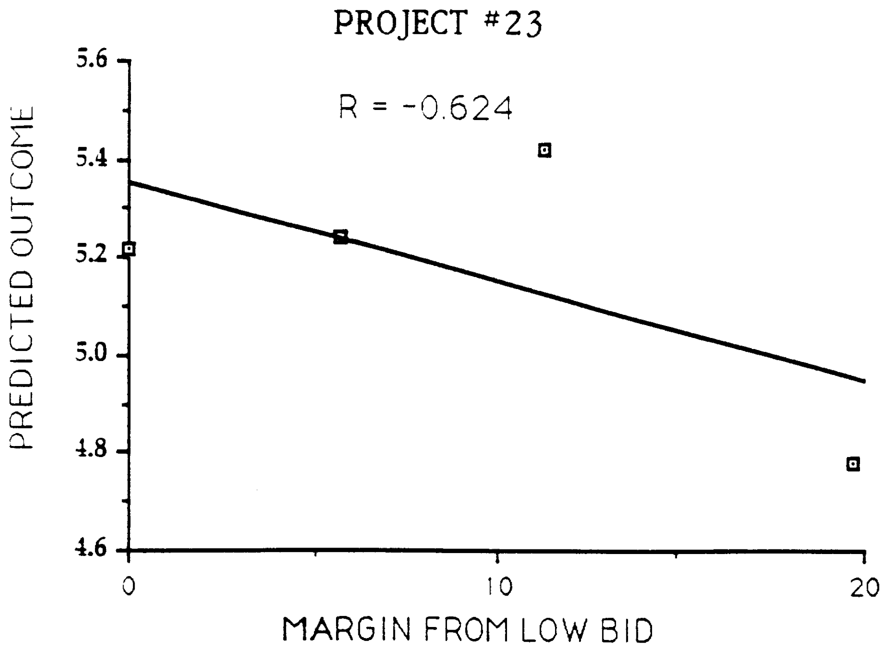
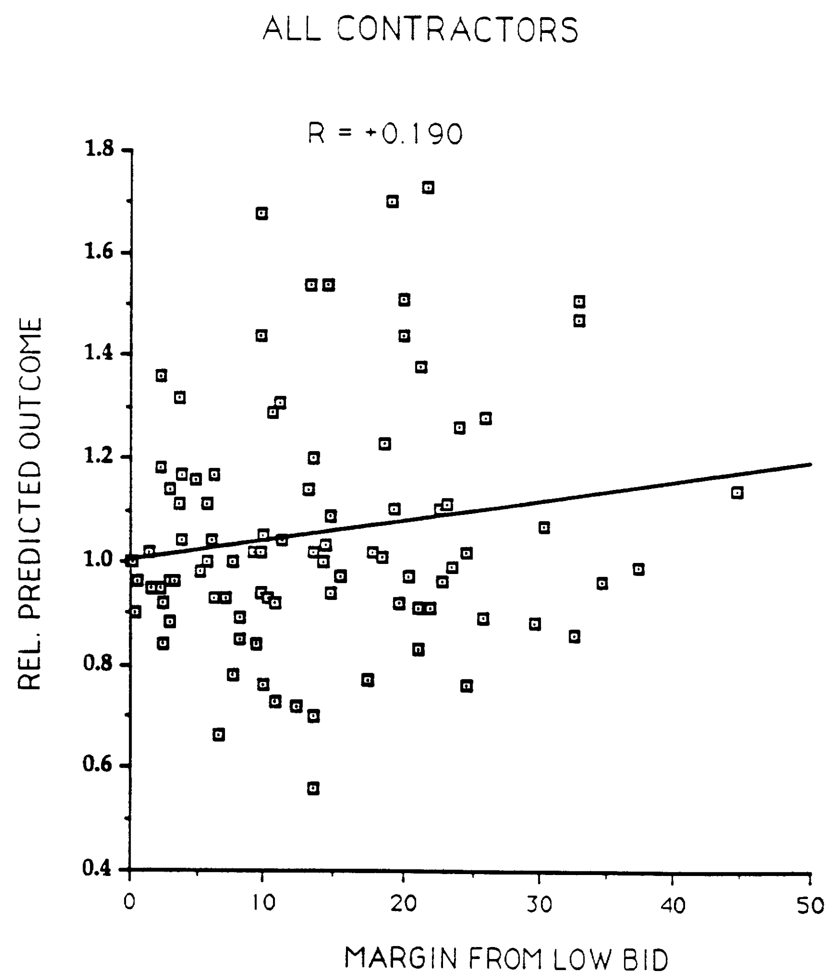
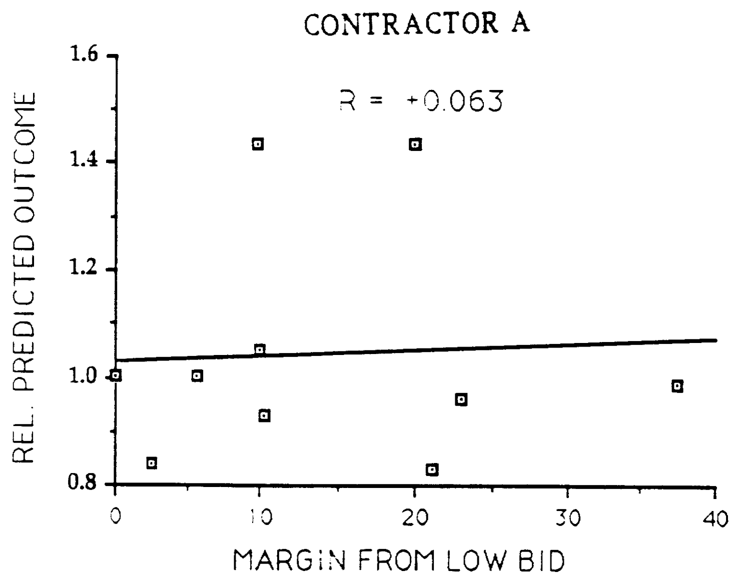

PROJECT #23
R = -0.624
5.6
5.4
5.2
5.0
4.8
4.6
PREDICTED OUTCOME
0
10
20
MARGIN FROM LOW BID

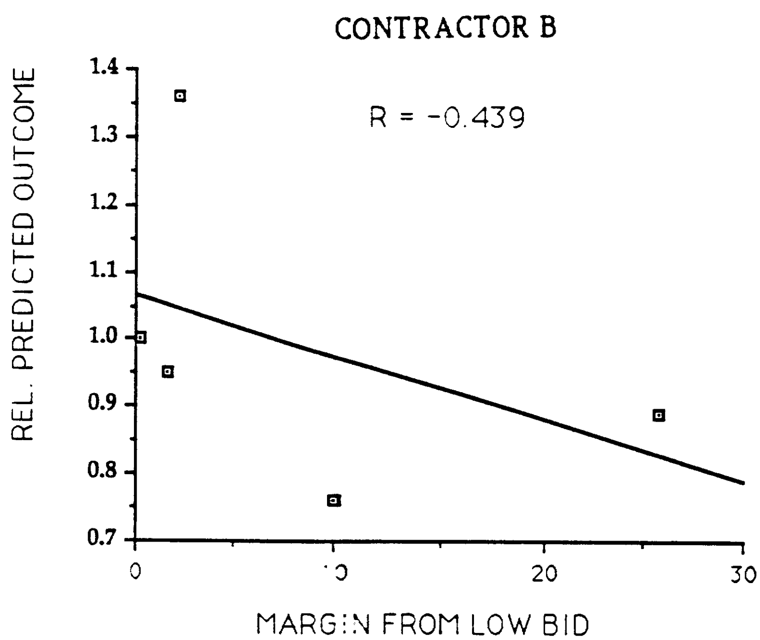
EXHIBIT 3a: Relative Predicted Outcome vs. Margin From Low Bid for Contractors



NOTE: RELATIVE PRED. OUTCOME = $\frac{\text{CO. PREDICTED OUTCOME}}{\text{PRED. OUTCOME OF LOW BIDDER}}$

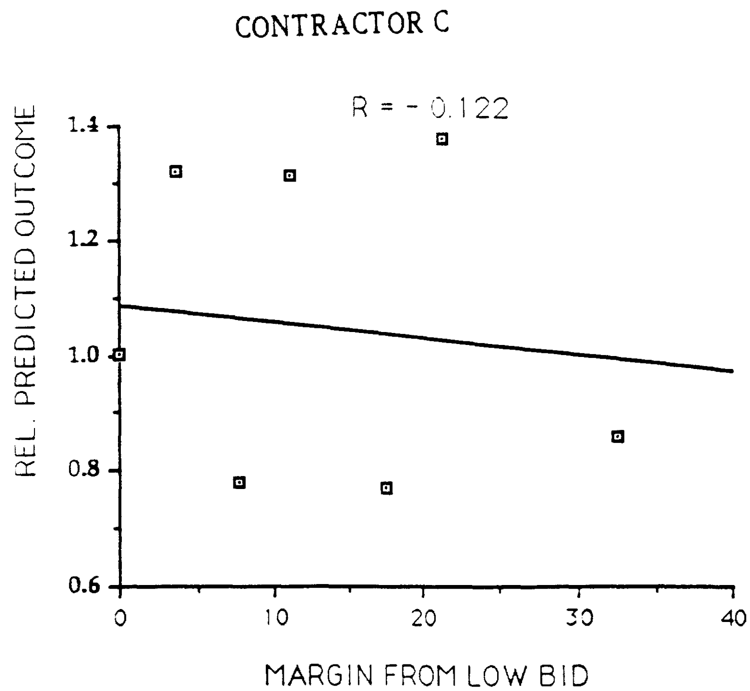
EXHIBIT 3b

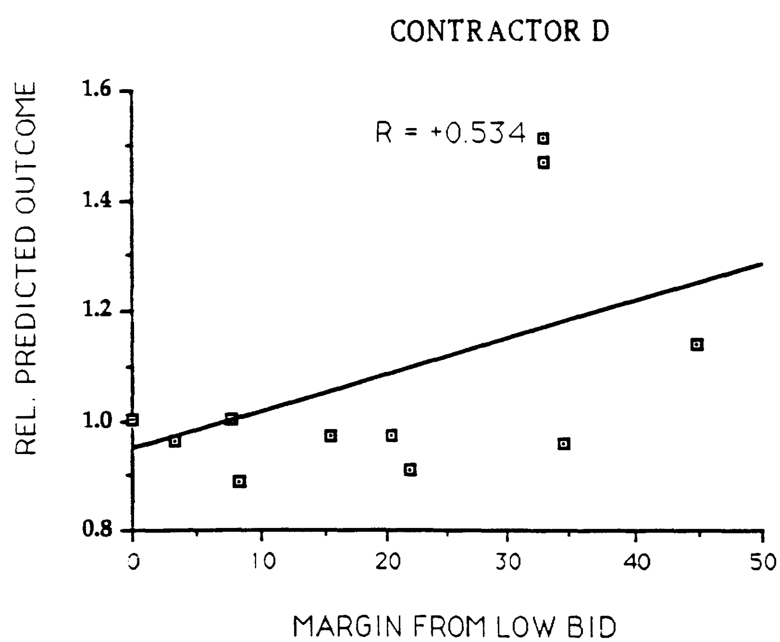




NOTE: Rel. Predicted Outcome = $\frac{\text{CO. PRED. OUTCOME}}{\text{PRED. OUTCOME OF LOW BIDDER}}$

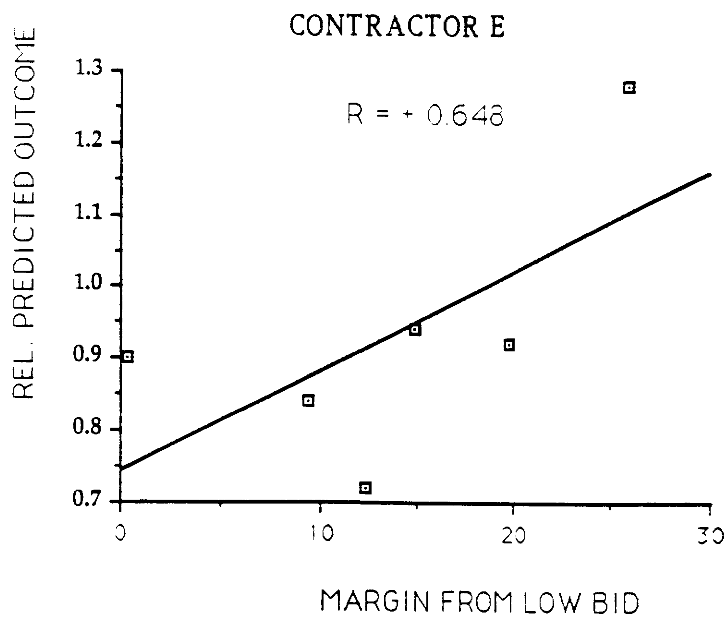
EXHIBIT 3c

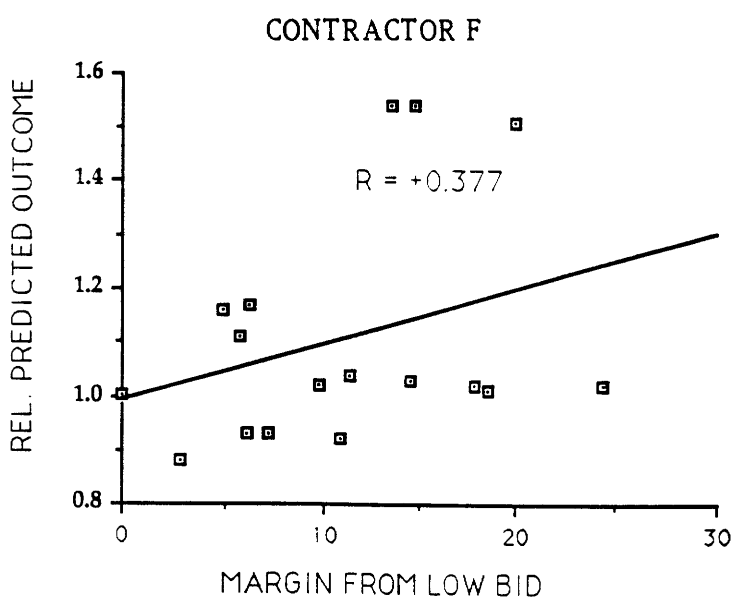




NOTE: Rel. Predicted Outcome = $\frac{\text{CO. PRED. OUTCOME}}{\text{PRED. OUTCOME OF LOW BIDDER}}$

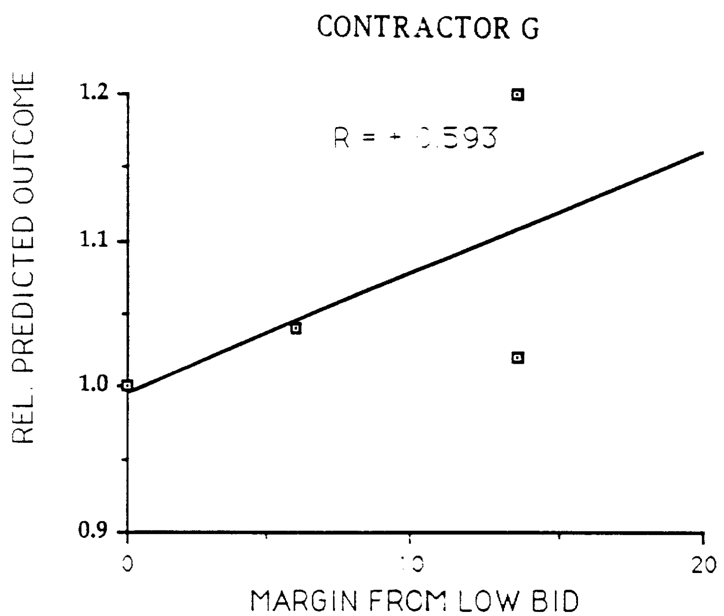
EXHIBIT 3d

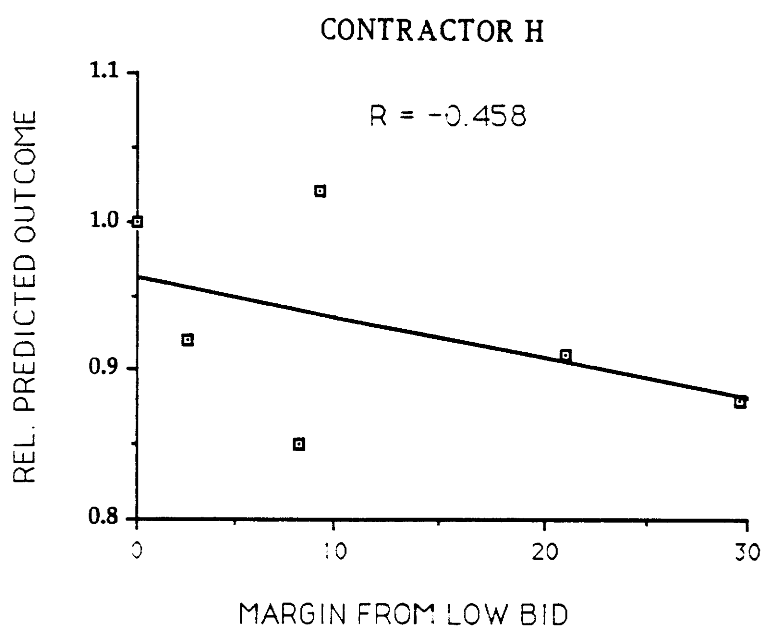




NOTE: Rel. Predicted Outcome = $\frac{\text{CO. PRED. OUTCOME}}{\text{PRED. OUTCOME OF LOW BIDDER}}$

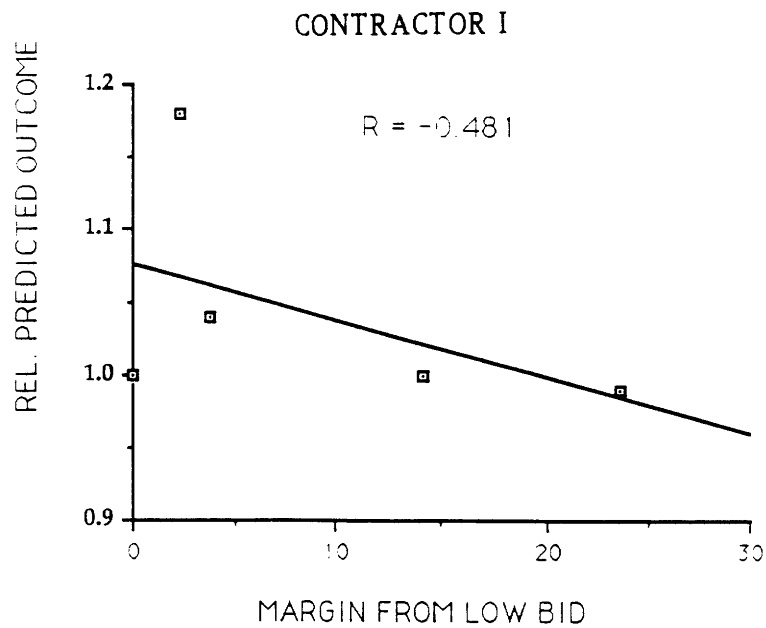
EXHIBIT 3e

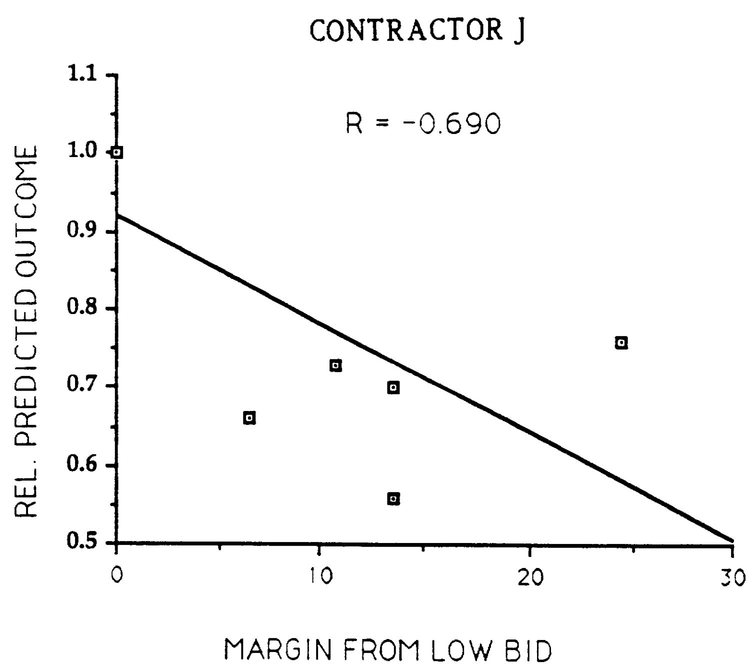




NOTE: Rel. Predicted Outcome = $\frac{\text{CO. PRED. OUTCOME}}{\text{PRED. OUTCOME OF LOW BIDDER}}$

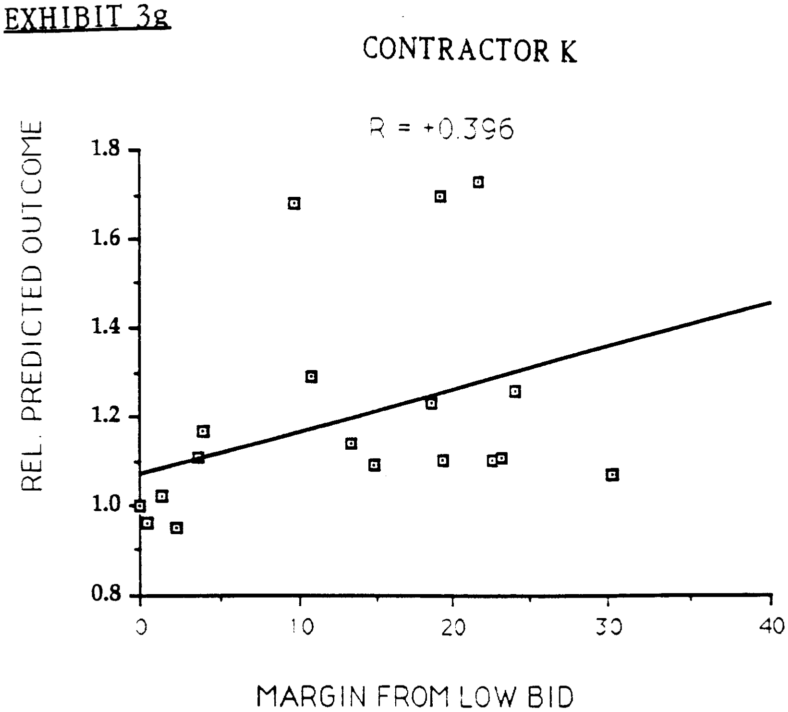
EXHIBIT 3f

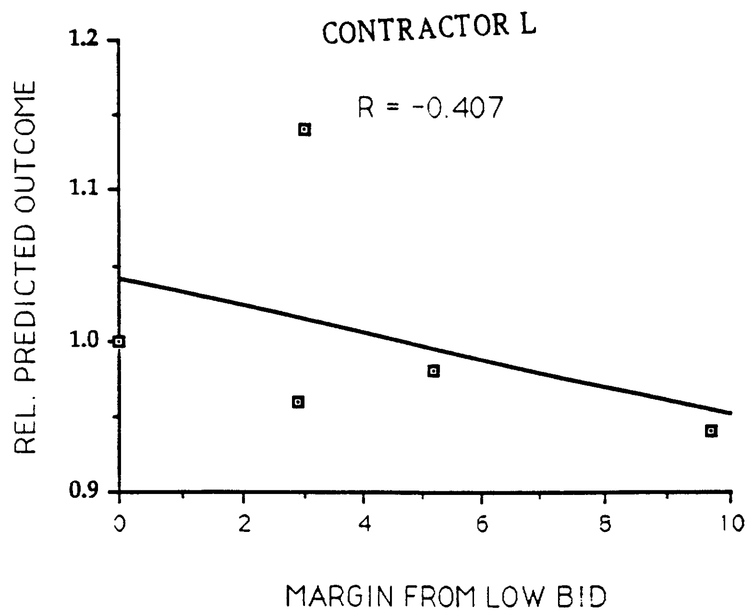




NOTE: Rel. Predicted Outcome = $\frac{\text{CO. PRED. OUTCOME}}{\text{PRED. OUTCOME OF LOW BIDDER}}$

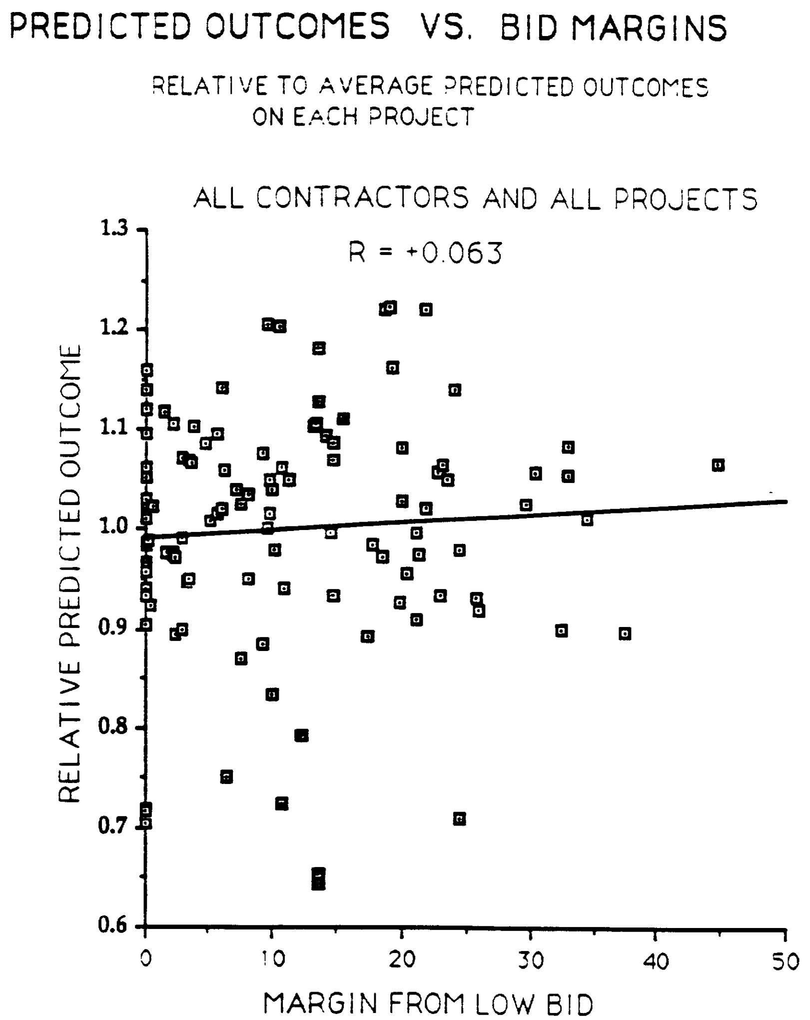
EXHIBIT 3g





NOTE: Rel. Predicted Outcome = $\frac{\text{CO. PRED. OUTCOME}}{\text{PRED. OUTCOME OF LOW BIDDER}}$

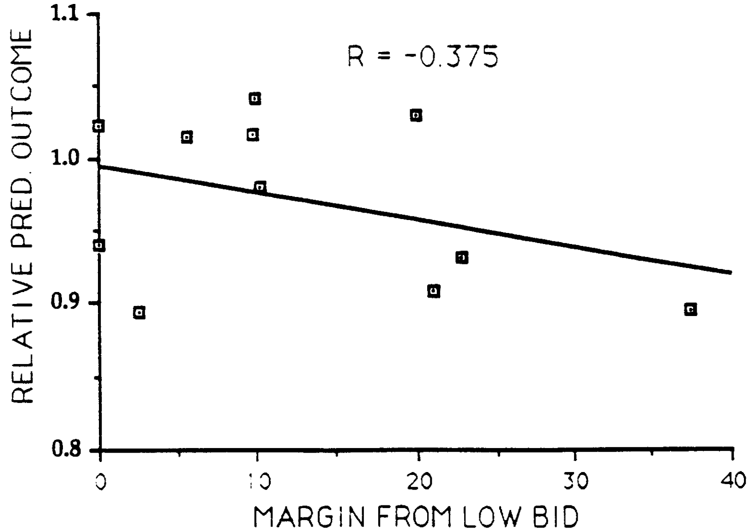
EXHIBIT 4a: Relative Predicted Outcomes vs. Bid Margins for Contractors



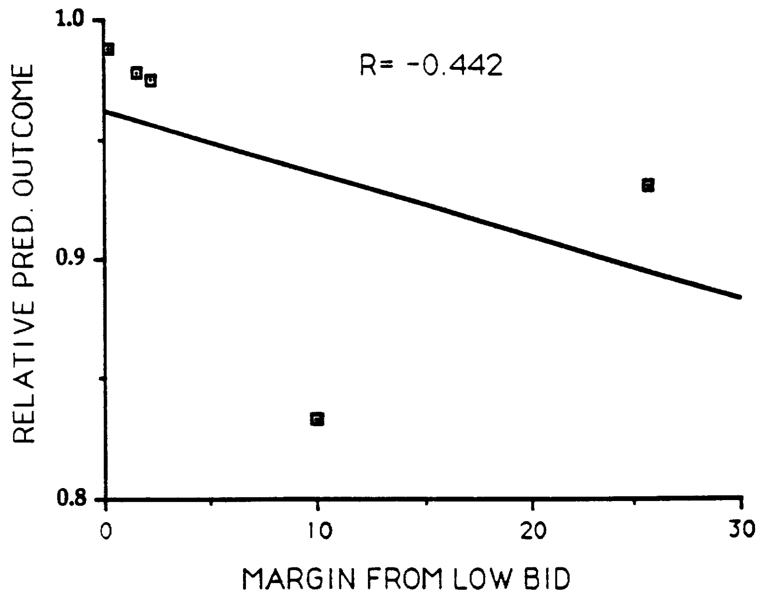
NOTE: REL. PREDICTED OUTCOME = $\frac{\text{CO. PREDICTED OUTCOME}}{\text{AVE. PRED. OUTCOME OF ALL BIDDERS ON THAT PROJECT}}$

EXHIBIT 4b

CONTRACTOR A

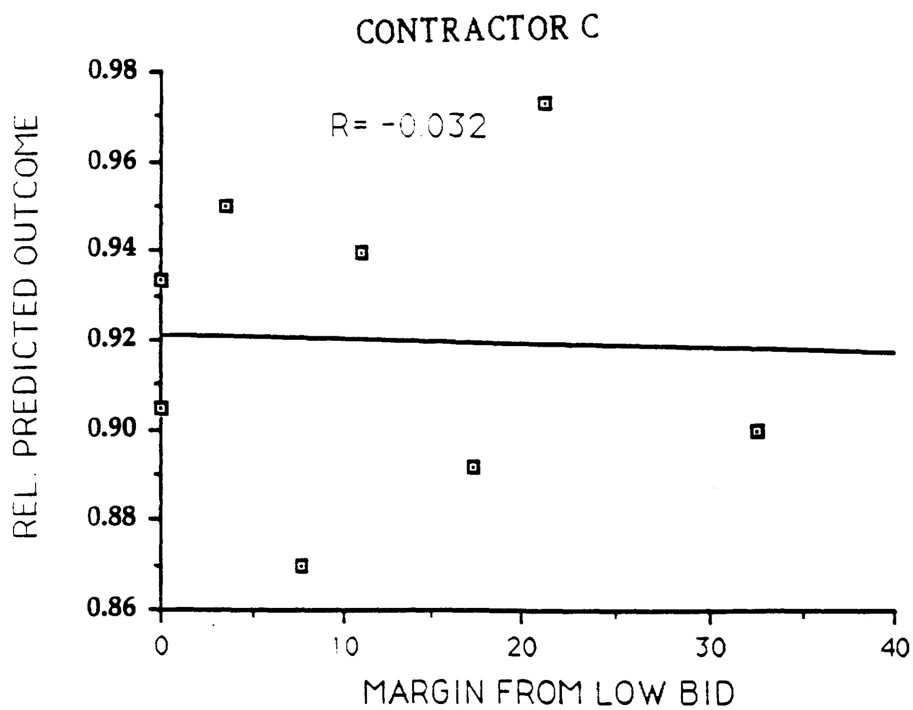


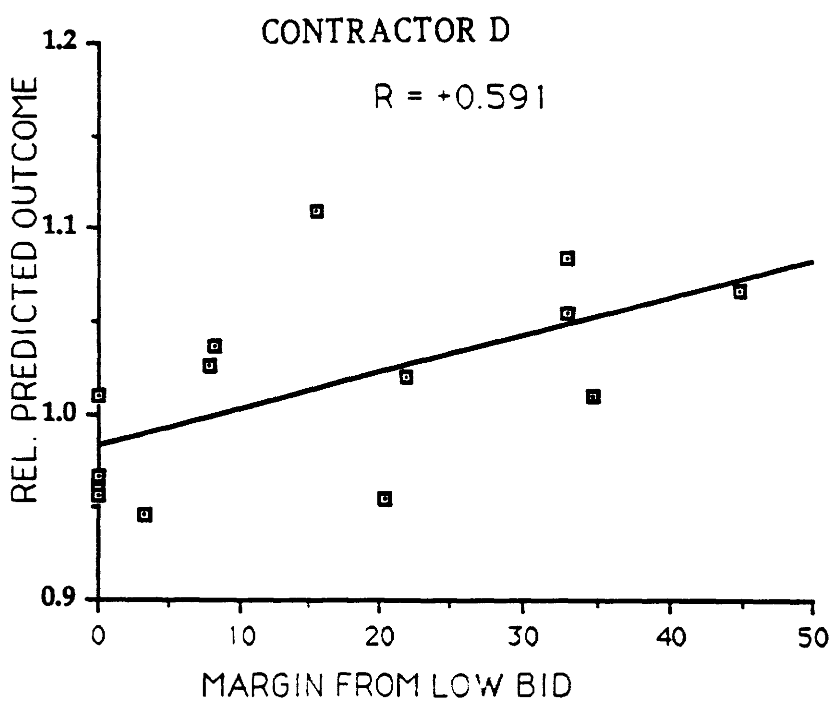
CONTRACTOR B



NOTE: REL. PREDICTED OUTCOME = $\frac{\text{CO. PRED. OUTCOME}}{\text{AVE. PRED. OUT. OF ALL BIDDERS}}$

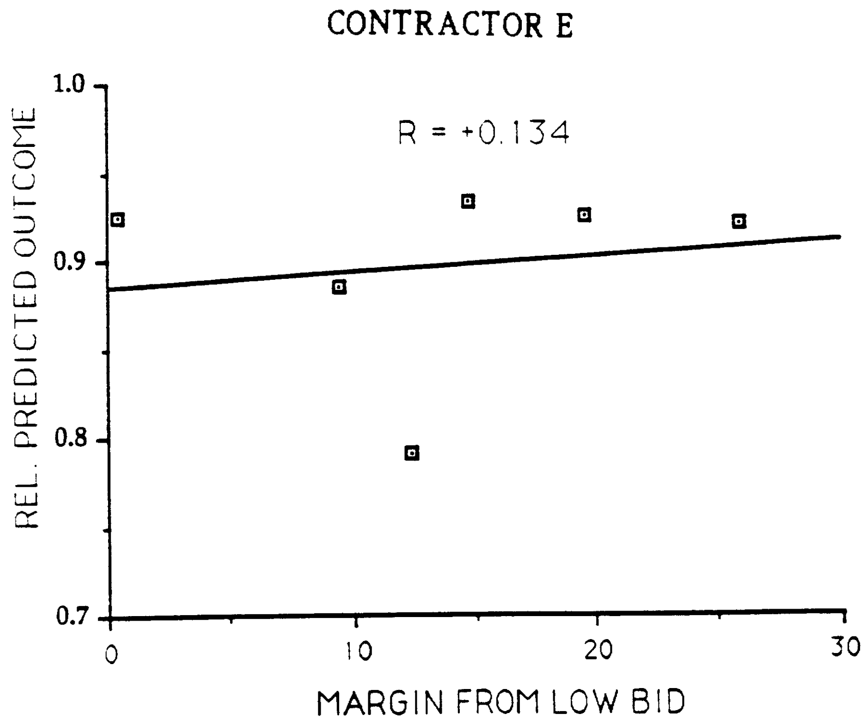
EXHIBIT 4c

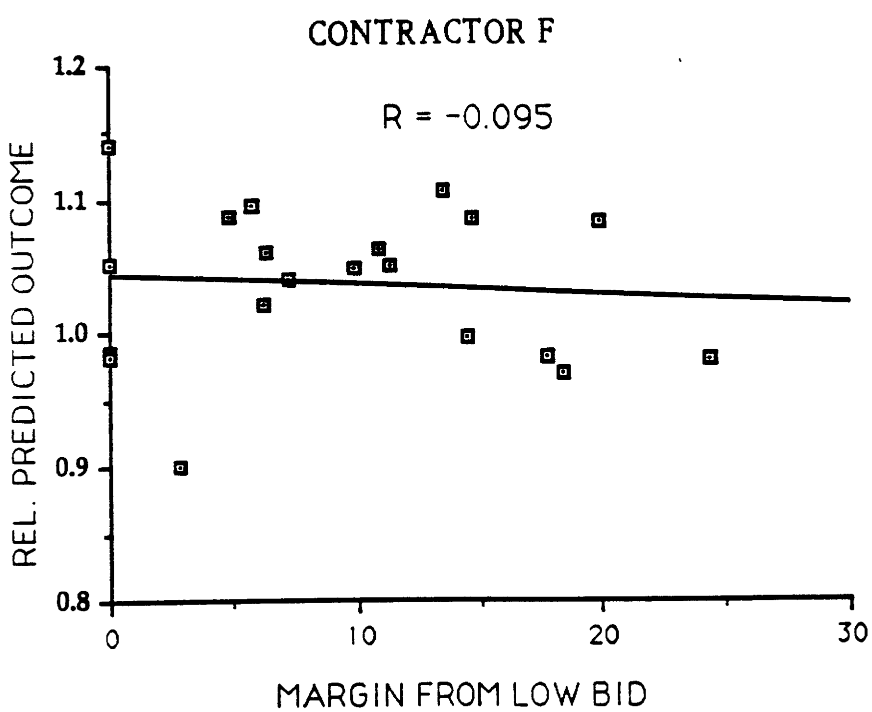




NOTE: REL. PREDICTED OUTCOME = $\frac{\text{CO. PRED. OUTCOME}}{\text{AVE. PRED. OUT. OF ALL BIDDERS}}$

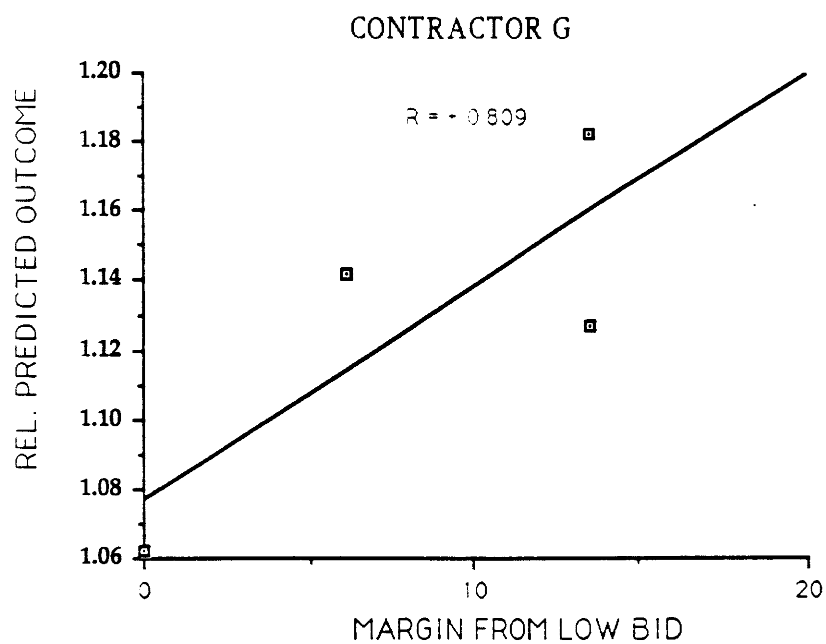
EXHIBIT 4d

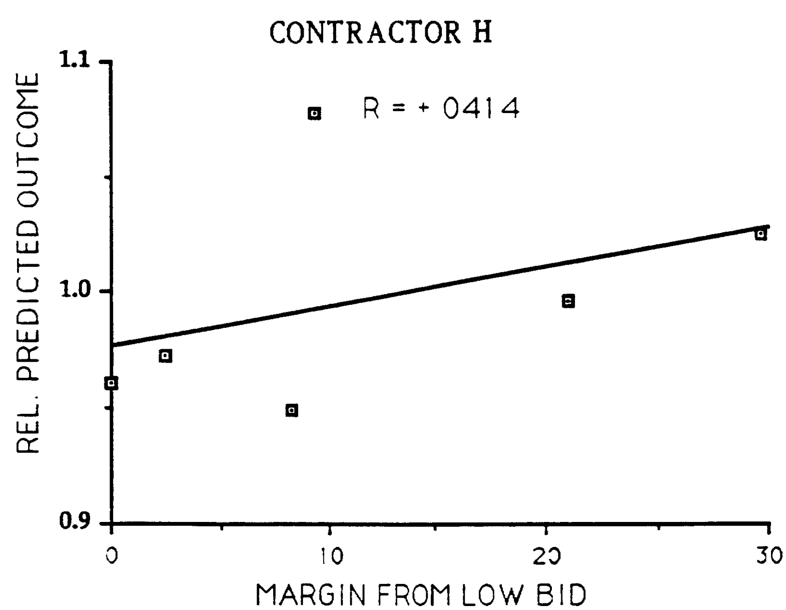




NOTE: REL. PREDICTED OUTCOME = $\frac{\text{CO. PRED. OUTCOME}}{\text{AVE. PRED. OUT. OF ALL BIDDERS}}$

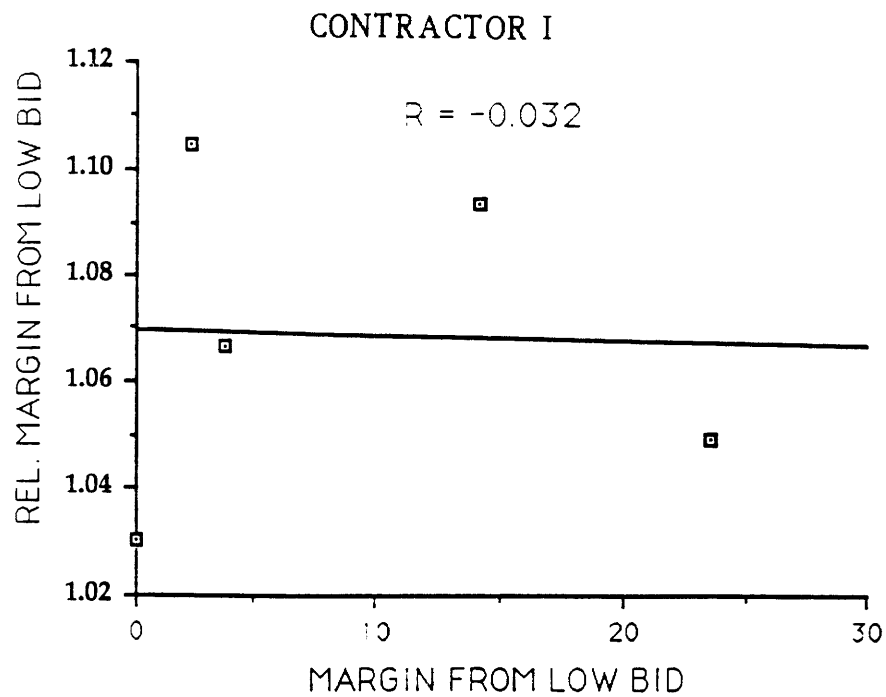
EXHIBIT 4e

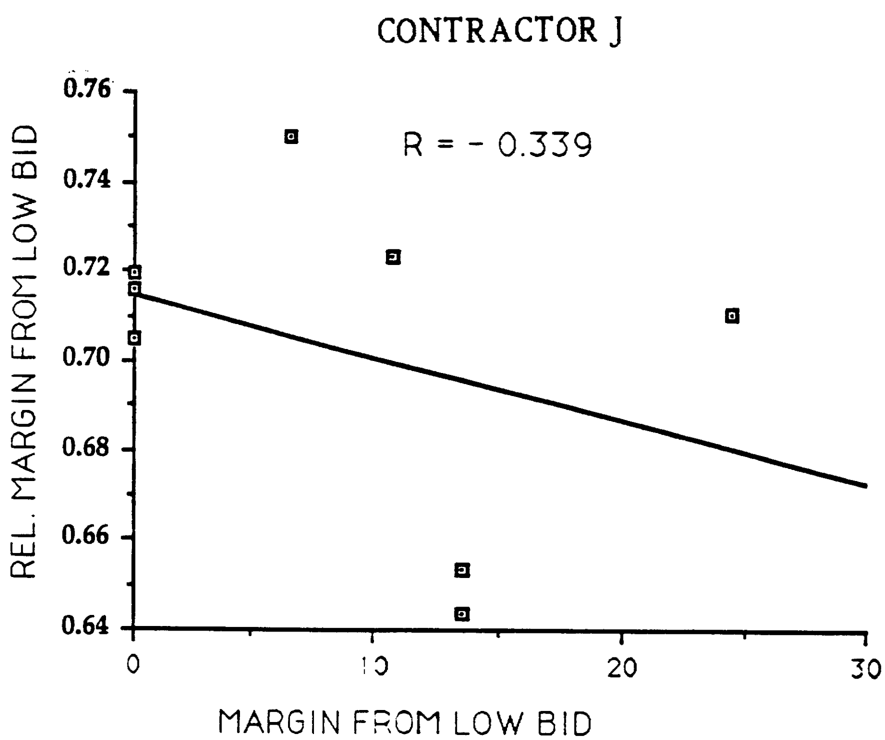




NOTE: REL. PREDICTED OUTCOME = CO. PRED. OUTCOME / AVE. PRED. OUT. OF ALL BIDDERS

EXHIBIT 4f

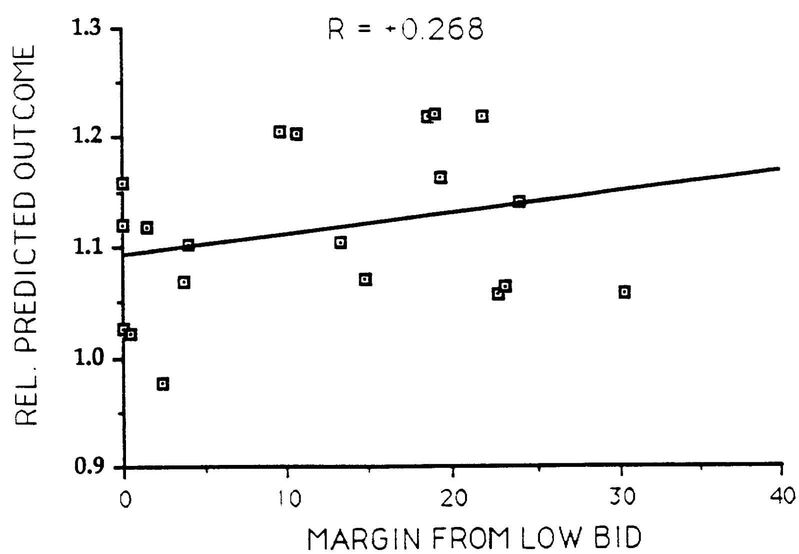




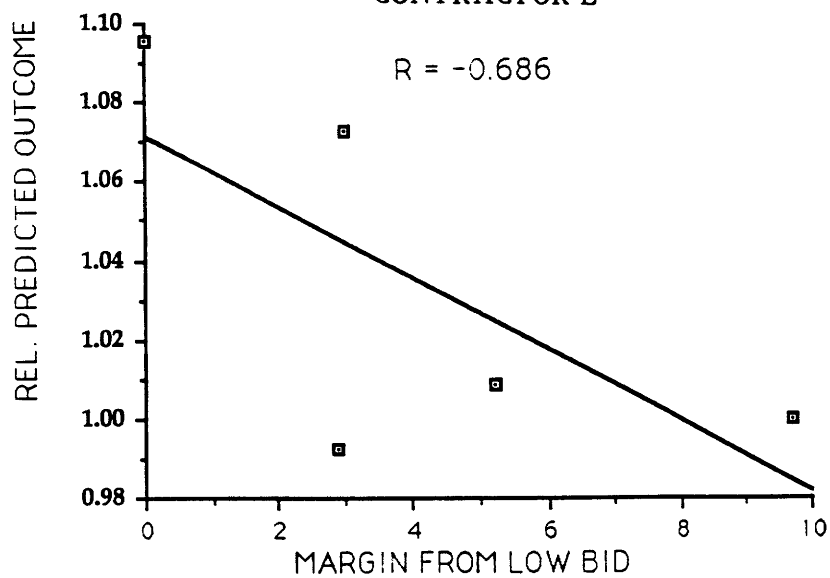
NOTE: REL. PREDICTED OUTCOME = CO. PRED. OUTCOME / AVE. PRED. OUT. OF ALL BIDDERS

EXHIBIT 4g

CONTRACTOR K



CONTRACTOR L



NOTE: REL. PREDICTED OUTCOME = $\frac{\text{CO. PRED. OUTCOME}}{\text{AVE. PRED. OUT. OF ALL BIDDERS}}$

EXHIBIT 5

Margins From Low Bid on Contracts
Before and After a Firm's Winning Contract

Contrtr.	Bids Before Win No.	Bids Before Win Margin	Bids After Win No.	Bids After Win Margin	Winning Contract As % of Ann. Revenues
A	1	2.5%	2	15.5%	16.0%
B	2	5.1%			
E	3	17.7%			
F	5	6.7%			
G			3	6.9%	6.8%
H	1	2.5%	2	18.3%	23.6%
I	3	9.9%	2	13.2%	3.9%
J			2	12.2%	4.8%
K	3	7.8%	4	7.3%	5.2%
L	4	5.2%	1	9.2%	1.7%
XX	3	3.2%			2.2%

Exhibit 6

Joseph Gioioso
Massachusetts Institute of Technology
Room 1-241 (617) 253-3880
77 Massachusetts Avenue
Cambridge, MA 02139

This research project attempts to measure to what extent the relative skill levels of General Contractors in various types of work is associated with the contractors' success in bidding projects. The study will focus on GCs who perform public works projects in the Boston area--specifically, contractors whose projects involve a wide variety of work types.

The two attached surveys attempt to quantify your perceptions of two different aspects of the Boston Public Works Construction market: the relative skill levels of different contractors in different phases of work, and the relative level of difficulty of the various phases of work on several recent Boston-area projects. For both surveys, I define **optimum performance** as:

1. minimizing rework and materials waste;
2. matching or exceeding the best possible schedule; and
3. maximizing manpower and equipment productivity.

Contractor Skills Survey

In the first survey, please rank how *skillfully* each contractor performs various work types. For a given work type, please consider a contractor's skill *relative to the skill of other contractors* (contractor A is better at excavation than contractor B) as well as the contractor's skill *relative to its skill in other work types* (Contractor A is better at excavation than at mechanical equipment installation). **A contractor's skillfullness is the extent to which the contractor can approach optimum performance as defined above.**

What if the GC usually Subcontracts out a given Work Type? If you believe the contractor typically **subcontracts** out a specific type of work, please rank the General Contractor's skill in *selecting and managing* the subcontractors for that work type. Please also mark that entry with an "S".

Scale: **4 = Superior, 3 = Better Than Average, 2 = Average, 1 = Below Average,**
0 = Don't Know, and S + Rank = Typically Subcontracted.

Project Difficulty Survey

The second survey asks you to rank the level of difficulty of various work types within public works projects which were recently bid and/or built within the Boston area. **Please rank the "difficulty" of the work types according to what fraction of contractors within this sample would achieve *optimum level of performance* (as defined above).**

*Most Difficult = most contractors would be unable to achieve optimum performance ;
*Not Difficult = nearly all contractors would achieve optimum performance.

Once again, your ranking of levels of difficulty should be *relative to the other projects*, as well as *relative to the difficulty of the other work phases within that project.*

Scale: **4 = Most Difficult, 3 = Very Difficult, 2 = Average Difficulty,**
1 = Easier than Most, 0 = Don't Know, X = Not Part of Project.

Please Note: This project is meant to investigate industry practices, and will not in any way comment on the Contractors' specific methods or successes. **The final research paper will keep all Contractors and questionnaire respondents anonymous**--no firm or individual will be refered to by name.

I thank you in advance for your assistance in my thesis work. I would be happy to discuss my findings with you at the conclusion of the project.

Contractor Skills Survey: Please rank the Contractors' skill in each of the Work Types. Most Skillful = minimum rework/waste; fastest schedule; and highest productivity.

Scale: **4=Most Skillful 3=Better than Average**
2=Average 1=Below Average 0=Don't Know
If Contractor usually Subcontracts The Work Type,
S + Rank = Skill at Choosing/Managing Subcontractor

Contractors \ Work Types	Excavations for Structures	Deep/Large Diam. Pipelines	Tunnelling	Mass Concrete (Foundations)	Thin Concrete (Elev. Slabs/ Beams, Parapets, Thin Walls)	Procurement/ Shop Dwg. Mngmt	Subcontractor Site Mngmt/Coordination	Mechanical Equip. Installation
A								
B								
C								
D								
E								
F								
G								
H								
I								
J								
K								

Optional: Name:________________

Position:________________

Firm:________________

Project Difficulty Survey: Please rank the Difficulty of each of the Work Types in each of the Projects.
Most Difficult = Most Contractors will have high rework, schedule delays, and/or low productivity.

Scale: 4 = Most Difficult 3 = Very Difficult
2 = Average Difficulty 1 = Easier than Most
0 = Don't Know X = Not Part of Project

Projects	Work Types	Excavations for Structures	Deep/Large Diam. Pipelines	Tunnelling	Mass Concrete (Foundations)	Thin Concrete (Elev. Slabs/ Beams, Parapets, Thin Walls)	Subcontractor Site Mngmt/Coordination	Procurement/ Shop Dwg. Mngmt	Mechanical Equip. Installation
Charlestown Pump Station (MWRA), 9/89									
Chelsea Sreen House (MWRA) 5/89									
Dartmouth WWTP 8/90									
Deer Island Switch Gear &Utilities(MWRA)4/91									
Deer Island Interim Sludge Trans(MWRA)6/90									
Deer Isl.Perm. Pilot Plant #5743 MWRA 12/91									
Payson Park Resevoir (Cambridge) 10/89									
Portland, ME. WTP 11/91									
Deer Isl. South Sytem PS #5733 (MWRA) 11/91									
Deer Isl. N. Main PS Modif. #5722 MWRA 6/91									
Deer Isl. N. Sys Headworks #5720 MWRA 5/91									
Early site Prep./PS Mod #5600 MWRA 12/89									
Early Siteworks/Earthworks #5601 MWRA 1/90									
Caruso Pumping Sta. E. Boston (MWRA) 1987									
I-93/Route 1 Interchange (JF White) 1988									
I-93/Route 1 Interchange at Tobin Br. (Sciaba) (2/91)									