An Evaluation of the Efficacy of Qualification-based Selection (QBS) Procedures for Architectural and Engineering Services

by

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Abstract of the Dissertation

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This study investigated whether a significant difference in construction cost and time growth existed in capital-facility construction projects due to selection procedures for Architectural/Engineering (AE) firms--based either on *qualifications only* (QBS), or a combination of *price and qualifications* (non-QBS). The sample frame consisted of 942 construction projects in the building, utilities and horizontal sectors ranging in value between 3 million and 50 million dollars. Of the 200 randomly selected projects mailed survey requests, 23 projects were returned completed, consisting of 35 construction contracts, 3 of which were owner-designed and excluded from the study. Of the 32 remaining construction contracts, 19 used QBS procedures for AE selection, and 13 used non-QBS procedures. A chi-squared goodness-of-fit test was used to evaluate self-selection bias due to the low rate of survey return, which found the returns reasonably representative of the population. One-way ANOVA procedures were used to compare construction cost and time growth, between QBS and non-QBS categories. No significant differences were found, indicating QBS procedures were not efficient, and suggesting that laws and regulation mandating the use of QBS procedures be revoked.

DEDICATION

I dedicated this work to all my descendents, now born, and yet to be born.

May your numbers be as the grains of sand on every shore and island.

May you find yourselves everywhere in the galactic rim and beyond.

Know by this work that in your veins runs the blood of genius and achievement,

and that all is possible through dedication, effort and persistence.

I charge you to prepare yourselves by education and experience

to master science, philosophy and religion,

and to take command of human destiny

so that you will be assured of survival, continuance-in-kind and prosperity

for yourselves and your descendents.

Simon Revere Mouer III

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SECTION ONE

INTRODUCTION

Statement of the Problem

Governments at the federal, state and local levels are often prone to promulgate laws and regulations without ever establishing a causal relation between the behavior to be regulated and the social benefits claimed or desired. At some point, which ordinarily should be prior to legislation, the efficacy of the laws and regulations should be statistically established--that the behavior to be regulated actually causes a significant gain in the social benefits claimed or desired.

Federal and state laws have already been enacted to regulate the procurement method of architectural and engineering (AE) services for the construction of capital facility projects [5, 72]. Such regulations, in general, require the use of "qualifications-based selection" (QBS) procedures and oppose price-based selection procedures, such as bidding, for procuring AE services. In the promulgation of laws and regulations requiring QBS procedures for AE selection, federal and state legislatures have implicitly assumed certain benefits that accrue to the public. One benefit claimed by proponents of QBS is that the additional money spent on using the best qualified AE firm is offset many times over by reducing or eliminating construction cost growth caused by AE omissions and errors generated in the planning, design, and construction management phases [7, 10, 12, 18, 32, 42-43, 47, 55, 70]. Implicit in this argument is that less-qualified AE firms are obtained by using non-QBS procedures--resulting in more AE omissions and errors--thus leading to more construction cost and time growth. Until now, the efficacy of these laws and regulations regarding the assumed benefits has never been established.

The Purpose of the Study

The purpose of this study was to evaluate the efficacy of laws and regulations requiring QBS procedures for the selection of an AE firm. The research evaluated the assumed benefit of minimizing construction cost growth, and construction time growth. If QBS were significantly efficient statistically, the laws and regulations would be justified. However, if QBS were not significantly efficient, or negatively efficient, then such laws and regulations must be questioned.

A secondary benefit of this study was the efficiency evaluation model presented, which may prove useful in assessing the efficacy of other laws and regulations.

Definitions of Terms

ABBREVIATIONS. The following abbreviations were used:

ACEC	American Consulting Engineers Council
ACSM	American Congress of Surveying and Mapping
AE	architectural or engineering firm
AIA	American Institute of Architects
ANOVA	analysis of variance procedure
APWA	American Public Works Association
ARTBA	American Road & Transportation Builders Association
ASCE	American Society of Civil Engineers
ASChE	American Society of Chemical Engineers
ASLA	American Society of Landscape Architects
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing Materials
COFPAES	Council on Federal Procurement of AE Services
FAR	federal acquisition regulations
FFE	furniture, fixtures and equipment
IEEE	Institute of Electrical and Electronic Engineers
LLE	long-lead equipment
NSBE	National Society of Black Engineers
NSPE	National Society of Professional Engineers
OSHA	Occupational Safety and Health Administration
PMI	Project Management Institute
PSMJ	Professional Services Management Journal
QBS	qualifications-based selection procedures
ROM	rough order of magnitude
SAME	Society of American Military Engineers
SWE	Society of Women Engineers

SYMBOLS. The following symbols were used:

α	significance level, ($1-\alpha$ = confidence level)
χ^2	chi-squared procedure result
μ or *M*	mean of a data set
ν	degrees of freedom
σ or *SD*	standard deviation of a data set
τ	equal to ΣX_i
B	subscript denoting between-categories sum of squares, also denotes bidding
c	subscript denoting cost growth set
e	efficiency, synonymous with efficacy
E	subscript denoting a frequency from the expected set
E^2	strength of significance, equal to v_B/v
f	frequency, or number or occurrences
F	ANOVA F-test result
H_0	null hypothesis
H_i	hypothesis, indices indicating whether primary, secondary, tertiary, etc.
i	indices, the i^{th} element of an array
j	indices, the j^{th} element of an array
k	number of columns, or categories
m	extra degrees of freedom lost in a χ^2 goodness-of-fit test
n	number of rows, or items
N	variable or subscript denoting non-QBS category
Q	variable or subscript denoting QBS category
R	subscript denoting frequency from the returns set
t	subscript denoting time growth set
v	total variance
v_B	variance between categories
v_W	variance within the category
V	subscript denoting *best value* selection procedures
W	subscript denoting the within category sum of squares
X_{ij}	Variable values in ANOVA procedure

CONSTRUCTION INDUSTRY TERMINOLOGY. The following terms have specific meanings within the construction industry and are presented in the chronological order likely to be encountered in a typical construction project.

Capital Facility. A capital facility is a facility occupying real estate, such as a building or a physical structure, which requires capital (money) expenditure to bring from concept to physical completion.

Construction. Construction implies the erection and/or placement of more or less permanent fixtures on real estate. Construction can be contrasted to manufacturing. Manufacturing produces objects that are mobile. An example is a steel mill. The mill itself is a facility to be *constructed* on specific site, while the steel products produced by the mill are *manufactured* and transported to buyers. Manufactured products may eventually be installed in a construction project. An example is steel I-beams. I-beams are manufactured in a steel mill, transported to a construction site, and installed as a permanent part of a building being erected.

Construction project. A construction project is an undertaking for the construction of a capital facility. A construction project may consist of one facility, or several different facilities, usually, but not necessarily, related to some common functions. Generally, a construction project infers a new facility. However, the renovation, rehabilitation, or modification of existing facility is often classified as a construction project.

Phases of a construction project. A construction project normally is executed in several stages, or phases. Project phases can be in defined in different ways. The Project management Institute (PMI)[57] suggests four stages: 1) feasibility, 2) planning and design, 3) production, 4) turnover and startup, as typical phases in a construction project. Such a description is sufficient for the academic study of function, but is not generally suitable for relating as to how an owner might contract for services.

For this study, project phases are defined by the probability that the phase might be performed by separate contract. Thus *feasibility* and *planning* are combined into one phase because it is more likely that one AE firm will be contracted to perform both these functions. *Design* is defined herein as a single phase because for some owners it is likely to be contracted to a different firm than planning. For example, for federal construction projects, a firm involved in *planning* is generally prohibited from performing the *design*. Instead of a single production phase, this study defines phases that might be contracted to different entities, such as *construction*, *long-lead equipment*, and *furniture, fixtures and equipment*. *Turnover* is a specific function that is generally included in the construction contract, and thus not necessary to separately identify for this study. *Startup* often is performed by a contract separate from the construction, and is defined herein as a separate phase. The primary phases of a construction project, then, from a contracting viewpoint, are defined herein as *planning*, *design*, *contracting*, and *construction*. The primary phases are traditionally sequential--that is, the previous phase is completed before the next phase begins. In addition to the primary phases, *project management*, *geo-technical investigation*, *long-lead equipment*, *construction management*, *furniture*, *furnishings and equipment*, and *start-up* may be separate parallel phases performed simultaneously with other phases, and all may be contracted to different service providers in the same project. In fast-track projects, normally sequential phases may overlap one another considerably.

Figure 1, below, depicts a typical traditional project with overlapping and sequential phases.

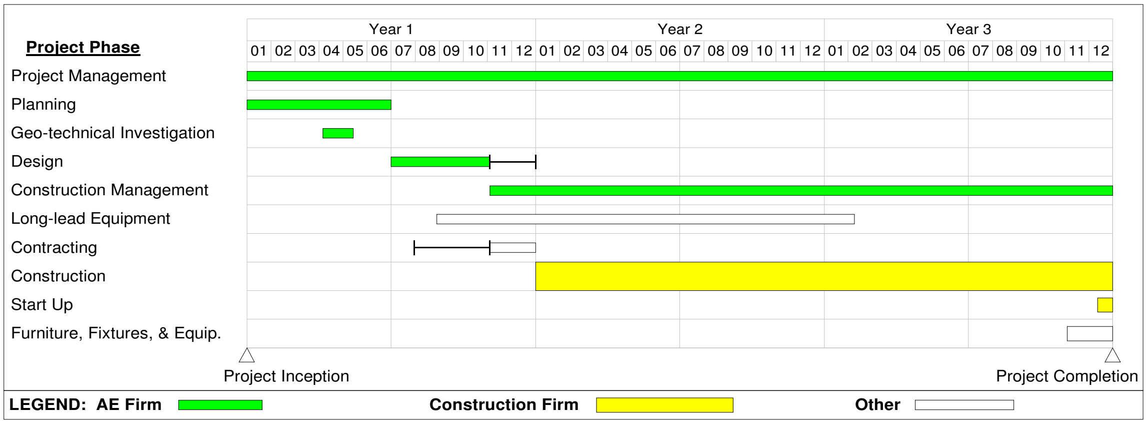

Figure 1. Typical Construction Project Phase Timeline

Architectural-Engineering Firm (AE). An AE firm is a firm that specializes in planning or designing facilities. The final design is completed in sufficient detail to construct the facility. AE firms usually have one or more licensed professional architects or engineers responsible for the finished drawings released for customer use. Many owners employ one AE firm to perform part or all of the planning stage, and another AE firm to perform all or part of the facility detail design.

A specialty AE firm is often contracted to perform a specific task. A geo-technical AE firm may be contracted to investigate subsurface site conditions, or provide foundation designs. An electrical/mechanical AE firm may be contracted to provide mechanical and electrical design. An AE firm specializing in construction management may be contracted to provide oversight of the construction contractor(s), and ensure their compliance with the technical specifications and drawings. In Figure 1, all the bars shown in green are typically performed by AE firms.

Project Management Phase. The project management phase is that phase and function that controls the project, and typically extends from project inception to project completion[57]. The project manager is typically the one person with knowledge of the project progress and performance from inception to completion. Project management may be performed by an individual or a team. Project management may be performed wholly or partially by the owner, or contracted to an AE firm.

Planning phase. The planning phase is that stage of a construction project prior to design, where the project feasibility, location, scope, and rough-order-of-magnitude (ROM) cost are formulated. Many alternate facility configurations and locations may be considered in the planning stage. Projects found feasible and funded are then scoped sufficiently for a design contract to be issued. Planning may be performed wholly or partially by the owner, and/or contracted to an AE firm.

Geo-technical investigation phase. The geo-technical investigation phase is that stage of a construction project where soil borings and subsurface investigations are made. The phase typically occurs during the planning stage when several sites may be considered. Owners want to know beforehand whether they are contemplating building on a marsh, quicksand, rock, or sinkhole. Geo-technical investigation may be extended into design, and is almost always performed by a specialty AE firm. Many owners contract for geo-technical investigation directly, while other owners may task the planning AE to subcontract for the task.

Design phase. The design stage is that stage of a construction project after planning, but before construction, where the facilities to be constructed are designed in sufficient detail to contract for construction. In a traditional construction project, design is completed before construction begins. In fast-track construction projects, the design is only partially complete when construction begins. Most construction projects require many professional disciplines to design a single facility. An architect may design the functional layout and appearance of the facility. A civil engineer may design the site layout, drainage, roads and parking lots. A structural engineer may design the facility super-structure. An electrical engineer may design the lighting and electrical power distribution. A mechanical engineer may design the heating, ventilation and air-conditioning systems, and perhaps the plumbing systems. A soils engineer may design the facility foundation. An interior decorator may design the furnishings and furniture. Design is typically performed by one or more AE firms, though an owner may perform some of the design himself, and may be heavily involved in the review of the design.

Contract. A contract is a binding agreement between two or more parties that is legally enforceable [26]. In the construction industry, contracts are either prime or subcontract. Most firms in the construction industry specialize in specific equipment and trades, do not venture far from their specialties, and generally contract as subcontractors. A few firms generalize in coordinating the activities of specialty firms, perform only a limited amount of construction tasks with their own work forces, and generally contract as prime contractors.

Prime contract. A prime contract is a contract directly between the owner, or the owner's agent, and the prime contractor[26]. The prime contractor may be an AE firm, a supplier of material or equipment, or a construction contractor. Owners traditionally execute a prime contract with a single design firm and a prime contract with a single construction firm. The prime contractors then may subcontract with specialty firms for design or construction of particular components. Some owners may assume the role of the prime design firm and execute prime contracts to several specialty AE firms. Some owners may assume the role of the general construction contractor and award prime contracts to several specialty contractors.

Subcontract. A subcontract is a contract between a prime contractor and supplier of materials or equipment, or a specialty subcontractor. Such subcontract is also known as a first tier subcontract, indicating it is directly with the prime contractor. Subcontractors may in turn subcontract further, in which case the subcontract may be a second or third tier subcontract.

Contracting phase. Owners typically contract for many services in the planning and design stages, as well as the construction stage.

Contracting the design and planning phases. Most owners perform some of the planning stage with their in-house personnel, and execute prime contracts for AE specialists as needed, such as geo-technical firms for subsurface investigation. A few owners maintain a staff of architects and engineers to perform detail facility design, but most owners will contract with one or more AE firms for detail design. Most contracts for AE services occur prior to construction, but may occur at any phase, such as the owner contracting with a specialty AE firm for construction management services. Some organizations, especially federal agencies, do not allow an AE that participated in the planning phase to participate in the design phase. Other owners may combine the planning and design phases in a single contract.

Contracting the construction phase. Owners typically contract for all facility construction, and the largest contracting effort typically is to award one or more prime construction contracts [26]. For traditional projects with sequential phases, the construction-contracting phase generally begins at the completion of design and ends at construction contract award. However, for projects with overlapping phases, the construction-contracting phase may overlap all phases. A solicitation of interest in a forthcoming contracting phase may be published in newspapers and among the construction industry publications several months before the design is completed. Design drawings, technical specifications, general provisions, special provisions, and the contract terms are assembled into one or more contract packages. A solicitation for bids, or a request for proposals, is published inviting construction contractors to submit bids or proposals. Interested construction firms are usually required to post a bid bond, after which they are supplied copies of the contract package. For very complex projects, owners may pre-qualify construction firms, and only request bids or proposals from those firms most qualified. Construction firms analyze the construction contract package, make material takeoffs, estimate labor and equipment requirements, contact material and equipment suppliers and subcontractors for quotes, and prepare a bid or proposal. The owner prepares his own estimate of construction costs, receives the bids or proposals, and evaluates them - often with the aid of the design team. In most government projects, any construction firm that will post a bid bond may bid on a construction project. However, before a firm can be awarded a contract, it must have either the lowest bid, or the proposal most advantageous to the government. In addition the firm must be found responsive to the invitation for bid, or the request for proposal, and the firm must be found to be responsible. The contracting phase may take several weeks to accomplish. The cost to a construction contractor to prepare a bid or proposal may vary from a few hundred dollars to tens of thousand dollars, depending on the size and complexity of the construction to be performed.

Long-lead equipment (LLE) phase. Some projects have specialized equipment to be installed which require a long lead-time from order to delivery. Such long-lead equipment is not a stocked item or kept in inventory. The equipment manufacturer will schedule the item into production only after receipt of a purchase order, after which he will order materials and assemble the item. The process may take from twelve to twenty-four months. When the lead-time requirement for LLE would require the purchase order be issued prior to the award of the construction contract, it is common for the owner to contract for it separately so that the construction project will not be delayed.

Furniture, fixtures and equipment (FFE) phase. Some projects may have a very specific interior furnishings plan, and elect to source furniture, furnishings and related equipment, such as light fixtures, door locks and key systems from select sources. When this occurs, it is common for the owner to contract for such FFE separately.

Construction phase. By far the most effort and cost expended to realize a construction project is in the construction phase. It is here that materials, equipment and skilled labor are brought together to assemble facility components in accordance with the plans and technical specifications, and in accordance with the contract requirements for timely completion. The classical construction phase consists of a single prime contract to a general construction contractor, who then manages and coordinates the activities of many specialty subcontractors and material and equipment suppliers. Increasingly, owners are issuing multiple prime construction contracts. Often an AE specialty firm in construction management is contracted by the owner to manage and coordinate the activities of the many prime contractors simultaneously on site.

Startup phase. For facilities that have outputs, such as power plants, refineries, and water and sewage treatment plants, a startup phase is necessary to check out all the systems and bring the plant to full capacity in stages. Buildings for commercial retail, and business offices, generally do not have a startup phase, but may have a commissioning phase for installed systems.

Qualifications-based selection (QBS). QBS is a specific selection procedure for choosing AE firms. The federal QBS requirements are set forth in the Brooks Act [35, 72], and require federal agencies to select an AE firm based only on the firm's qualifications to perform the work. The owner, or his agent, generally evaluates the qualifications of interested AE firms, ranks them according to such things as their experience, principal employees, and number of like jobs performed. The most qualified firm is selected, and the price is then negotiated. In the event the government and the selected AE firm are unable to reach agreement on price, the government may terminate the selection and proceed to select the next best-qualified AE firm.

Non-qualifications-based selection (Non-QBS). For this study, all procedures that are not QBS procedures are non-QBS procedures. Non-QBS procedures include bidding, auctioning, and combinations of qualifications and price generally known as best-value contracting. All non-QBS procedures base selection partly or wholly on price. Despite the legal requirements for QBS selection procedures for AE firms, many are selected otherwise. And many exceptions exist at the federal and state level, permitting AE selection by non-QBS procedures. Most engineering activities do not require a permit or submission of drawings or analysis by licensed engineers. Examples of such professional activities are electrical and electronic design, mechanical design, subsurface investigation, community planning, construction management, and the design of vehicles such as automobiles, motorcycles, ships and aircraft.

Schedule. In the construction industry a schedule is a tool for tracking progress towards project or contract completion. Most construction contracts require the construction contractor to develop and maintain a construction schedule in sufficient detail so that the owner may assess the probability that the project will be completed on time. Some owners develop a master schedule for complex projects involving several construction contractors, or contract with an AE firm specializing in construction management to do so. A schedule may be as simple as a bar chart, but more likely is a critical-path network of activities, each activity with a time duration, linked together to form a network and reveal critical-sequence paths requiring intensive management.

Equitable adjustment. An equitable adjustment is a change in contract price or time that contractor is due for within-scope change orders issued to him, or for material changes in contract terms, such as differing site conditions necessitating a stop-work order[26].

Change order. A change order is a directive by an owner, or his agent, to a contractor to make a change to the specifications or drawings, or work, that is considered within the scope of the contract[26]. In such a case, the contractor is obligated to perform as directed. The contractor usually submits a request for an equitable adjustment in price or time because of the change order. Owners usually prefer to pre-price change orders before issuing a notice-to-proceed, but contractors generally prefer to accomplish the change order, then submit for an equitable adjustment. More often than not, an owner will issue a notice-to-proceed with a change order before an agreement for an equitable adjustment price or time can be reached in order to prevent construction delay impact from occurring. Many owners include a "not-to exceed" price limitation in such unpriced change orders.

Modification. A modification is a change to the contract documents agreed to by both parties[26]. Ultimately all change orders result in a contract modification incorporating the change in the contract documents, including changes in price and time. Some owners procrastinate in issuing such modifications until the contract is complete, hoping to offset the cost of additional work against contract deletions and contractor assessments of liquidated damages for late contract completion. A contractor is not obligated to perform changes proposed by the owner that are out of the scope of the contract. All such out-of-scope changes are known as cardinal changes, and a modification to the contract is generally performed before a notice to proceed is issued.

Liquidated damages. Liquidated damages are pre-determined cost assessments that will be applied against a contractor for late completion of the contract [26]. Liquidated damages are typically stated in dollars per day, and generally cover the owner's administrative costs to continue oversight of the contractor. Liquidated damages may also include the costs of alternative facilities required because of the delay. Courts generally refuse to enforce any part of liquidated damages that are deemed punitive.

Time Extension. A time extension is additional time granted by the owner to the contractor for performing the contract. Most construction contracts provide for extensions of contract time for unusual acts impeding the progress of construction that are not due to the fault or negligence of the contractor. Examples of such acts are stop-work orders by the owner or his agent, change orders for additional work, unusually severe weather, strikes, natural disasters, civil unrest, and war.

Claim. A claim is a request by a contractor to an owner for an equitable adjustment [26]. Most claims arise from differing interpretations of the contract documents by the contractor and the owner. If the contractor receives a clarification that is different than what he bid or proposed on, and his interpretation is reasonable, he may claim for an equitable adjustment in contract price or time. Other claims may arise because the owner interfered with the contractor, impeding his progress. Owners who fail to resolve claims may spend far more in attorney fees litigating the matter in court if the contractor is persistent. Unresolved claims may take months or years to resolve.

Lifecycle Costing. The Project Management Institute (PMI) [57] defines lifecycle costing as "The concept of including acquisition, operating, and disposal costs when evaluating various alternatives." Lifecycle costing may be performed in the feasibility stage, early in the planning phase, and may also be performed in the design stage in selecting components that balance construction costs against operational costs.

Limitations of the Study

SAMPLING LIMITATIONS. The items measured in the study were *construction contract cost growth* and *time growth* attributable to an AE firm's fault or negligence. The primary sampling unit was the construction *project*.

A construction *project* may yield multiple construction *contracts* and multiple AE firms. Each construction *contract* may yield none, one, or several change orders or *modifications*, some of which may be attributable to an AE firm. The distribution of such change orders and modifications in the population of construction contracts was unknown. The distribution of construction contracts in the population of projects was also unknown. For this study it was assumed that randomly selecting *projects* sufficiently randomized *construction contracts*, which sufficiently randomized construction contract modifications of *cost and time growth*, so that meaningful population predictors could be determined from the sample.

SCOPE. An evaluation of the entire universe of all construction projects that have ever occurred since the promulgation of the Brooks Act enacted in 1972 was impractical for the following reasons:

1. Construction projects are temporary undertakings, and the principal parties temporarily gathered to execute the project are disbanded after completion. Most often the project planners, project constructors, and facility operators after construction contracts are different groups of people.

2. Data for construction projects completed for more than a few years would be difficult to obtain, as project files are routinely archived, forgotten, and often discarded or destroyed.

3. The most knowledgeable project personnel, generally the project manager and his team, are usually relocated to new projects and seldom remain with the completed project.

For the above reasons, and also to keep the study within a reasonable cost and time for an individual researcher, this study was narrowed to explore only a limited sector of the construction industry and a limited number of projects due to be completed by the time survey requests were mailed.

The sampling frame was limited to recently completed projects of general buildings, horizontal facilities and utilities, ranging in cost from three million to fifty million dollars. Complex structures such as high rise structures, refineries and manufacturing facilities were excluded, as well as rehabilitation and renovation projects. Older completed projects (those completed for more than a few years) were excluded because project records and institutional knowledge relevant to this study were likely inaccessible. Uncompleted projects were likewise excluded because the data needed for this study would be incomplete.

RECORDED DATA VERSUS RECALLED AND JUDGMENTAL DATA. While most of the data collected was based on records kept during project execution, the study also relied heavily on the recall and judgement of the project manager for the assignment of responsibility for causes of change orders and modifications to project contracts. This reliance on the project manager's recall and judgement was necessary because AE firms typically severely limit their contractual liability for consequential damages due to their errors and omissions [26, 70]. Consequently, owners seldom documented and were even less prone to sue for delay or damages caused by their AE firm's lack of diligence. Also, the contract modification document itself did not typically reveal the fault or root cause of its creation, as seldom was the contractor at fault whose contract was being changed or modified.

SAMPLE SIZE. A sufficiently large sample of two hundred projects was polled. However, the survey instrument was sufficiently complex, and the recipients preoccupied with other work, that a low rate of return occurred, which was not unexpected. Mail-in surveys typically have rates of return as low as five percent, or less [24, 39]. Follow-up, reminder post cards [24] raised the rate of return to 17 percent. Such low rates of return could introduce self-selection bias [24]. Self-selection bias was evaluated using a chi-squared test for goodness-of-fit, which is presented in Section 4 Results.

THREATS TO VALIDITY. The known threats to validity were as follows:

1. **Multiple causes** of construction contract cost and time growth,
2. **Time growth** measurements may introduce bias from two sources:
    a) shorter contracts might be lost in the effects from longer contracts, and
    b) *contract* time growth is not necessarily a *project* time growth or delay.
3. **Absolute dollar cost** measurement may introduce bias from two sources:
    a) costs can vary enormously for very similar projects, and
    b) smaller contracts might be lost in the effects from larger contracts.
4. **Self-selection bias** can be introduced if low survey response rate occurs.
5. **Other benefits** are claimed for QBS procedures for AE selection, other than a reduction in cost and time growth.

Multiple Causes. The study controlled threats from multiple causes of contract growth by identifying the root causes of a modification and allowing variances only to those that were the fault of an AE firm. In the case of partial fault, the magnitude of the growth was adjusted proportionate to the percent fault. Root causes fell into the following broad categories:

- Unanticipated acts beyond the control of the owner or any prime contractor (e.g., acts of God, war and civil disturbances, strikes)
- Acts and responsibilities of, and risks reserved to, the owner (e.g., notice to proceed, rights of way, differing site conditions, and change orders)
- AE failure to adequately perform a contractual responsibility, including AE design errors and omissions
- Acts of the construction contractor delaying himself
- Interference from other prime construction contractors,

Of the above causal categories, only construction contract changes and modifications attributable to the failure of an AE to adequately perform a contractual responsibility, including design error or omission, were allowed to vary. All other contract changes and modifications were assigned a zero growth value, as they are outside the purview of the AE to control or influence.

Time Growth. Construction contracts normally incur time growth. Contracts of long duration are not unusual and can be expected to have a greater time growth than contracts of shorter duration. For example, 108 calendar days or more would not be unusual time growth for an original contract duration of 1,080 days. And 27 calendar days or more would not be unusual time growth for an original contract duration of 270 calendar days. If contract time growth were evaluated using calendar days, contracts of long duration would typically appear to fare worse than those of short contract duration. If contract delays are summed together the effect of shorter contract delays becomes muted or lost in the effects of the longer contract delays. To avoid such bias, contract time growth was reduced to a percentage or ratio, arrived at by dividing the additional time granted in calendar days by the original contract duration in calendar days.

Contract time growth is not necessarily *project* time growth. In the case of a project with a single construction contract, contract time growth does represent project time growth, but in the case of a project with multiple simultaneous construction contracts, time growth on one contract does not necessarily translate into a project delay. In order to properly evaluate project time growth when multiple construction contracts exist, a detailed review and analysis of the project schedule for concurrent delay or use of schedule float would be required. Such analysis was beyond the scope of this study.

Some of the factors causing the precise evaluation of contract time growth to require examination of the project schedule are[26]:

- Concurrent schedule delays
- Delays absorbed by schedule float
- Limited nature of liquidated damages to gauge time value
- Propensity of owners to award additional time but not additional money

In addition to the above, the following complications tend to occlude the analysis of time growth[26]:

- Limited use of incentive contracts
- Reluctance of owners to divulge return-on-investment data
- Lengthy time to settle delay impact claims
- Cost of borrowed money

Absolute Dollar Costs. Project costs for facilities with identical functions can vary enormously. Some factors that can cause a facility cost to vary are[52]:

- Location (region of the country, urban or rural, seismic zone, adjoining structures, environmental mitigation requirements, remoteness of site.)
- Time of year constructed (cold weather, rainy season, holiday season)
- General economic climate (depression, recession, economic boom)
- Competition for resources (availability of labor, materials, and equipment)
- Style and elaboration (facade, ornamentation, refinement, prestige)

In addition, owners typically reserve five percent or more in contingency funds for normal cost growth. A $40 million construction contract could reasonably be expected to have a $2 million cost growth, while a $4 million dollar project would only expect $200 thousand. If project performance would be based on absolute dollars, the larger construction contract cost growths would appear to fare worse and the cost growth of smaller contracts would appear relatively insignificant in comparison. To eliminate the possible skewing of the study results towards larger dollar value contracts, all absolute dollar values were converted to relative values by dividing the dollar value of cost growth by the original dollar value of the construction contract.

Self-selection Bias. Self-selection of respondents associated with a low survey return rate is a potential threat to validity and was evaluated by using a chi-squared test for goodness-of-fit.

Other Benefits. Proponents of QBS claim other benefits for QBS besides reducing construction contract cost or time growth. These other claimed benefits were evaluated in Section 2 Review of the Literature.

SECTION TWO

REVIEW OF THE LITERATURE

Proponents of QBS

Organizations. The following organizations have published or publicly expressed support for QBS procedures for AE selection:

• American Consulting Engineers Council [7]	(ACEC) *
• American Congress of Surveying and Mapping [6]	(ACSM) *
• American Institute of Architects [3, 4, 8]	(AIA) *
• American Public Works Association [10]	(APWA)
• American Road & Transportation Builders Association [11]	(ARTBA) *
• American Society of Civil Engineers [12]	(ASCE) *
• American Society of Landscape Architects [15]	(ASLA) *
• Council on Federal Procurement of AE Services	(COFPAES)
• National Society of Professional Engineers [54]	(NSPE) *

* member of COFPAES

All the above organizations are professional societies representing their constituent technical disciplines or industries. Most private consultants are members of one or more of the above organizations. COFPAES is a lobbying organization which represents member concerns in federal and state legislatures and promotes QBS procedures. All of the pro-QBS literature found appears originally authored by members of one of the above societies or organizations, generally representing the organization's official view.

There was an abundance of articles and papers supporting QBS procedures authored by individual members or published by the above organizations [2, 4, 19-21, 23, 25, 27-28, 32, 42-43, 48-49]. Sufficient comment is provided in the Annotated Bibliography for most of the articles reviewed and no further specific comment was provided herein for such publications that were based solely on argument and logic, i.e., with no statistical data presented supporting the author's viewpoint. A summary of these arguments is presented below under Arguments.

Only one AE publication, issued by the AIA, had some statistical data, which is discussed below under Case Study. In addition, COFPAES contracted with the University of Texas to perform a statistical study, which is discussed below under Independent Review.

Arguments. The arguments that proponents make for the use of QBS procedures for AE selection are summarized as follows [7, 10, 12, 18, 32, 42-43, 47, 55, 70]:

1) *Construction cost & time growth*. Less AE errors and omissions occur with QBS selected AE's, resulting in less construction cost and time growth.

2) *Safety*. Safer designs are produced by QBS selected AE's leading to less facility failures, construction accidents, or operational failures.

3) *Innovation*. More innovative designs are produced by AE's selected by QBS procedures.

4) *Environment.* More environmentally sound designs are produced by AE's selected by QBS procedures.

5) *Lifecycle costing.* AE's selected by QBS procedures are more prone to recommend and provide lifecycle costing, balancing construction, operations, and maintenance costs over the life of the facility.

6) *Qualifications.* Only QBS selected AE's submit their qualifications for the particular work and thus the best qualified firm is more likely selected.

Evaluation of Arguments. The study only evaluated statistically the contributions of cost and time growth benefits. The other claimed benefits of QBS are easy to make and difficult to verify. Some of the other benefits claimed are questionable because the AE is typically not contractually responsible for them and/or typically refuses to warrant or guarantee any performance related to them. None of these other claims were potential threats to validity of the study just because they state an alternative purpose for QBS procedures. In a broader study, legitimate multiple benefits could be assessed statistically. These other claims are evaluated as follows:

1. *Safety.* Safety of the facility design, operational safety of the facility, and safety during construction are three separate issues.

a. Safety of the facility design, i.e., the structural integrity of the facility during and after construction, and the safe design and operation of systems within a facility are typically the responsibility of the AE firm designing such. Design AE firms typically limit their liability for design errors and omissions to reissuing corrected drawings and generally resist and refuse to undertake liability for consequential damage for facility safety or performance. Whether AE firms selected by QBS procedures provide safer designs than those AE firms selected by non-QBS procedures remains to be verified statistically and was beyond the scope of this study.

b. The Occupational Safety and Health Administration (OSHA) sets standards and enforces safety violations on the construction site, not the AE. Safety during construction is the responsibility of the construction contractor, not the design AE. An owner may contract with a specialty AE firm for construction management services and charge the construction manager with enforcing construction safety, but even then such enforcement is limited to issuing a stop-work order until the safety deficiency is remedied. Construction management AE firms typically refuse to be liable for the unsafe acts of the construction contractor. Evaluating construction safety is feasible, but linking safety performance to AE design would be difficult at best since the AE typically has no contractual liability for construction safety and resists warranting or guaranteeing such performance. The assessment of construction safety was beyond the scope of this study and was not further evaluated.

c. The Occupational Safety and Health Agency (OSHA) sets standards and enforces safety violations on the facility site during operations. The AE may have some responsibility for ensuring that OSHA, ASTM and other standards are incorporated in the design, but operational safety is primarily the responsibility of the operator, not the AE. AE design firms typically refuse to be liable for the unsafe acts of the facility operator. It is difficult to reconcile this claimed benefit without a clear contractual obligation on the part of the design AE and a reasonable justification for otherwise refusing to warrant or guarantee safety performance during operations. The assessment of operational safety was beyond the scope of this study and was not further evaluated.

2. *Innovation.* Innovation in design may be a valid benefit of QBS, but it may also be a two-edged sword in that untried designs may entail greater risks for the owner. Evaluating such risks may involve far more than just AE facility design, entailing market evaluation, revenue generation projections and profit potential, which are generally out of the purview of AE firms. Methods for measuring risk already exist. A generally accepted tool for measuring innovation objectively is lacking. The assessment of innovation was beyond the scope of this study and was not further evaluated.

3. *Environment.* Environmental assessments may be a valid benefit of QBS, but it is no small undertaking and seems more a contractual scope matter than a selection process matter. Where government permits and environmental laws are necessary to be complied with, owners typically employ a legal and environmental specialist, rather than rely solely on the design engineer. Owners cannot shift the legal burden of responsibility for complying with environmental laws and regulations, and AE firms typically limit their liability in such matters to correcting the drawings and technical specifications. The assessment of environmental benefit was beyond the scope of this study and was not further evaluated.

4. *Lifecycle costing (construction, operations & maintenance).* The evaluation of the lifecycle costing argument is set forth below. An in-depth assessment of lifecycle costing benefits from QBS-selected AE firms versus non-QBS-selected firms was beyond the scope of this study.

a. Lifecycle costing is a desirable contract scope requirement to balance initial construction costs against probable operational and maintenance costs. It is more a contract scope issue than an AE selection process issue. It may also be relevant to feasibility and marketing studies that determine investment payback time and revenue and profit generation potential. Whether AE firms selected by QBS procedures provide better lifecycle benefits than AE firms selected by non-QBS procedures was not known and was not evaluated in this study.

b. Most capital facilities have relatively long useful lives--typically twenty-five years or more. Performance evaluation over the useful life of such a facility would require data collection over the entire life span of the facility, which was far beyond the scope of this study. Owners and owner competitors are probably the best sources for such information, and few AE firms are likely to make detailed estimates beyond estimating a percentage of completed facility cost.

c. The cost of a facility depends on many factors besides structure and function. Owners vary considerably in their taste for quality, ornamentation, and style. Facility location and timing also may affect cost. As an analogy, Lamborghini and Yugo automobiles both provide basic automotive transportation. The Yugo provides very low-cost and utilitarian transportation with little comfort and frequent maintenance. The Lamborghini provides the same transportation in comfort, luxury and style at a price an order of magnitude or two greater than the Yugo. The owner decides based on his taste, income and needs. Similarly, owners vary greatly in what they want their facility to represent, what their budgets can fund, and their needs. A basic office function might be designed as an imposing and intimidating seat of power, such as a courthouse or a presidential palace--heavy on excess structure and space. A highly successful business may utilize the same office function in a more utilitarian facility at a cost significantly lower. The AE designs the facility accordingly and the cost estimate follows. Thus it is the owner's desires, budget and need that drives the ultimate cost of a facility, not the AE.

d. AE firms typically refuse to warrant or guarantee their lifecycle costing estimates. The American Society of Civil Engineers (ASCE) [12] is a strong proponent of QBS procedures for AE services and a member of COFPAES. The ASCE advocates lifecycle design costing but has this to say about warranting or guaranteeing their work (bold emphasis added):

> *The inclusion of warranty or guarantee clauses in contracts for engineering services has been proposed as a way to enhance facility design and longevity …Warranty and guarantee clauses create an absolute liability on the part of the warrantor or guarantor and obligate the engineer with regard to matters beyond their control, such as pre-existing construction in rehabilitation projects and post-construction maintenance and enforcement of facility use restrictions …* ***ASCE opposes the use of warranty and guarantee clauses*** *…*

5. *Qualifications.* The evaluation of the "qualifications" argument is set forth below. The assessment of the relative qualifications of AE firms was beyond the scope of this study and was not further evaluated.

a. Proponents often present their case as if there are only two alternatives for acquiring AE services -- QBS or bidding. The Federal Acquisition Regulations, FAR Part 15.101, allow for a combination of qualifications and price through competitive proposals in a process often called *best-value* contracting where both price and qualifications can be evaluated and weighted with award to the proposal most advantageous to the government.

b. Even in straight bidding, owners, including the federal government, may require submission of financial data, past work performance and qualifications to determine if a bidder is *responsible*. The Federal Acquisition Regulations (FAR Part 9.104) sets forth the standards for *responsibility* that a bidder must meet before an award to the low bidder can be made. These include the following:

1) adequate financial resources
2) able to meet the delivery or performance
3) satisfactory performance record
4) satisfactory record of integrity and business ethics
5) necessary organization, experience, accounting and operational controls, and technical skills

c. QBS procedures very likely do result in very highly qualified AE firms being selected for federal government projects because an extensive evaluation and ranking system is in place, applied to a large number of AE firms. However, it does not necessarily follow that state and local governments have such an evaluation and ranking system in place. Moreover, it is unlikely that private owners have access to an AE database that would allow them to compare the qualifications of AE firms, much less evaluate and select the best-qualified firm.

d. AE professionals typically require a five-year university degree, a comprehensive basic entry test after graduation, a number of years of relevant experience, a final professional test, and recommendation of one or more licensed AE's before they can obtain professional registration and license to practice on their own. Thus there is a minimum experience level built in to every licensed architect or engineer.

Noncommittal Organizations

The following organizations may or may not support QBS procedures for AE selection. No publications were found voicing an organizational position.

- American Society of Mechanical Engineers [16] (ASME)
- Institute of Electrical and Electronic Engineers [13] (IEEE)
- American Society of Chemical Engineers [9] (ASChE)
- National Society of Black Engineers [54] (NSBE)
- Society of American Military Engineers [63] (SAME)
- Society of Women Engineers [64] (SWE)

Opponents of QBS

Critics of QBS procedures were not as vocal as proponents were. Little organized resistance to QBS procedures for AE selection was evident and publications were few. Such critical literature as did exist complained that the act was inherently biased toward large, established firms and discriminated against new, small, and minority firms [42]. The American Consulting Engineers Council (ACEC) [7] identified the following entities as obstacles to wider use of QBS procedures, or questioning the necessity for QBS procedures:

- US General Services Administration
- The US Senate Governmental Affairs Committee
- US Department of Housing and Urban Development
- US Office of Management and Budget
- US Small Business Administration.

Independent Review

PSMJ. The Professional Services Management Journal (PSMJ) [58] is an independent organization that gathers data on the economic performance of AE firms, compiles this data into an annual report and sells the report to AE subscribers and the general public. PSMJ did not directly address the issue of the efficacy of QBS procedures, but it did note widespread use of non-QBS procedures among AE firms.

PSMJ reported that price-based selection occurred in selections by private owners, other service providers, construction contractors, and, to the extent that a licensed engineer or architect was not required to perform the service, public agencies at the federal, state and local levels. Pricing considerations in the selection of a design service provider were significant in the public sector as well as the private sector.

University of Texas. COFPAES contracted with the University of Texas for statistical study of QBS versus price-based selection procedures [70]. A literature review was accomplished and a preliminary report issued, but no statistical data was collected or analyzed. The occurrence of price-based selection procedures for AE firms was noted. COPAES canceled the research after receipt of the preliminary report.

The literature search performed by the University was incorporated into this study. A survey questionnaire was included in the report but was unused. That survey instrument would not have gathered sufficient information to directly control for confounding factors contributing to construction contract cost and time growth and was not used for this study.

Federal government

Full and Open Competition. The normal procedures for the federal acquisition of services and goods are codified in Federal statutes 10 U.S.C. 2304 and 41 U.S.C. 253 which are embodied in the Federal Acquisition Regulations (FAR) Part 6 [34]. With certain limited exceptions, federal contracting officers must permit all *responsible* sources to compete for government contracts. In addition FAR Part 6 sets two primary means of complying with the requirement: competitive *bidding*, and competitive *proposals*. Competitive bidding requires award to the lowest-priced bid from a responsible bidder. Competitive proposals may consist of a combination of factors, including qualifications and price, and award must be made to the proposal most advantageous to the government. The competition in contracting policies embodied in the Federal Acquisition Regulations (FAR Part 6.003) define full and open competition as follows:

> *Full and open competition, when used with respect to a contract action, means that all responsible sources are permitted to compete.*

Brooks Act. The Brooks Act is an exception permitted to full and open competition. It was passed in 1972 as Public Law 92-582 (PL 92-582), and codified in 40

U.S.C. 541-544[72]. FAR 36.6[35] implements the Brooks Act and sets forth the specific procedures required to be in compliance. The Brooks Act applies to federal acquisitions of Architect and Engineer (AE) services from private firms. The Brooks Act does not apply to AE services performed by employees of public agencies.

The Federal Acquisition Regulations (FAR6.102(d)) states that the selection process promulgated by the Brooks Act "is a competitive procedure." It is *limited* competition, however, not *full and open* to all responsible sources. AE firms considered less qualified will not be considered for selection. For pricing, QBS procedures are sole-source negotiations, since pricing is discussed only with a single firm. Both the term "sole-source" and "negotiations" are terms that experienced public procurement officials usually associate with higher acquisition costs when compared to bidding for services[70].

The Brooks Act requires federal agencies to select an AE firm based only on the firm's qualifications to perform the work. The federal agency generally pre-qualifies interested AE firms, ranks them according to such things as their experience, principal employees and number of like jobs performed. The most qualified firm is selected and the price is then negotiated. In the event the government and the selected AE firm are unable to reach agreement on price, the government may terminate the selection and proceed to select the next best-qualified AE firm.

The Brooks Act is limited to professional AE services that are required by state law to be performed or supervised by a registered or licensed professional. There is no federal registration or licensing of architects or engineers by the federal government. Recurring attempts have been made both to weaken and to strengthen the Brook's Act[70].

State Governments

Thirty-seven states have enacted statutes very similar to the federal Brooks Act requiring QBS procedures to be used for the selection of AE firms for the design of state public projects [5]. Twenty-eight applied QBS requirements to state contracts and fourteen states required local governments to employ QBS procedures for AE services [5]. Five states prohibited a private AE firm from responding to a bid request from either a public or private invitation or solicitation and provided sanctions against a practitioner who contracted for professional work based on non-QBS selection procedures [5].

Eight states had enacted statutes that required or allowed a combination of qualifications and price, or restricted QBS procedures to vertical construction, or had a threshold before QBS procedures were applicable [5].

Many other government and quasi-government agencies, districts, boards, and other public service providers appeared to practice selection of the project designer based primarily on price, regardless of laws apparently to the contrary [47, 58, 70]. A/E firms subcontracting work to smaller A/E firms often did so based primarily on price [47, 58, 70]. The American Congress on Surveying and Mapping [6] stated in an annual report:

> *It is very common for architectural and engineering firms that have been awarded a federal contract under qualifications-based selection (QBS) procedures to subcontract surveying and mapping work for the project on a low-bid basis.*

Judicial Decisions

Anti-trust complications. The American Society of Civil Engineers (ASCE) and other professional societies at one time promulgated ethics clauses in their by-laws, which held competitive bidding for professional engineering and architectural services to be unethical [43]. The Justice Department ruled that such provisions violated anti-trust laws. The ASCE and other professional societies were forced to remove these provisions from their by-laws and regulations [43]. This effort by the Justice department has been largely superceded and circumvented by state legislation that required the use of QBS selection procedures for AE services, and those few states that prohibited an AE firm from bidding on any work, public or private [5].

Court Cases. Allegations have appeared in court cases contesting the selection of one design firm over another. Without disputing such allegations, the federal courts have nevertheless upheld the Brooks Act, and it has withstood all such challenges [30-31, 53].

Case Study - Florida vs. Maryland:

There was only one publication found in the literature that had statistical data for comparing costs of QBS and non-QBS projects. The AIA commissioned a study comparing the state of Florida (QBS) and the state of Maryland (non-QBS) [1]. There was no discussion of cost or time growth of construction contracts due to AE omissions or errors, and thus the AIA study results were not applicable to the proposed research. Moreover, the AIA study did not perform any statistical process ruling out random chance as a confounding factor.

Nevertheless, The AIA study was interesting because it was used to promote and justify a change in Maryland's AE procurement laws [73]. An in-depth, detailed evaluation of this AIA report is presented in Appendix A, which concludes that the findings of the report must be considered inconclusive

SECTION THREE

METHODOLOGY

Overview of the Study

The study utilized survey research techniques to gather data on construction contract cost and time growth associated with AE errors or omissions. The primary sampling unit was construction projects listed in FW Dodge's[37] database of construction projects. Sampling was limited to apparently completed projects of new facilities in specific industry sectors that were within a specific dollar range. The survey instrument was sent to the owner's project manager, if identified, or to the owner's head office.

Non-QBS procedures are illegal in many jurisdictions and sanctions may be taken against firms not complying with QBS procedures for AE selection. Potential respondents employing non-QBS procedures may not answer truthfully, or not answer at all, if the specific term "QBS" is used in the survey instrument and/or the data is traceable back to the respondent. Thus, the terms "QBS" and "non-QBS" were not used in the survey instrument. To further allay any concerns of the respondent the instrument itself did not identify the participant, and all information relating the participant to the data was destroyed once the data were reviewed and verified. Data on the project were reduced to ratios or percentages, so that specific project data could not be traced back to a participant.

Participants

The items measured in the study were construction contract cost and time growth. The primary sampling unit was the construction *project*. The target participant for furnishing information was the owner of the project, or, more often, the owner's project manager, which in some cases was the AE firm that designed the project. The FW Dodge database of construction projects was sampled to obtain a listing of potential projects, and to obtain data for contacting the owner or project manager of the projects selected.

The participants responding to the survey request were promised anonymity in writing, and in accordance with procedures set forth under Instruments, below. The purpose of the study was presented to the participant as an effort to extend the FW Dodge data with actual completion data to allow future research and study.

There is no known database listing construction contract change orders and modifications. Such data were extracted from the returned surveys. The database of construction projects sampled was developed and maintained by FW Dodge, a company which has gathered project data for over seventy-five years. FW Dodge initiates its data collection effort on pending projects that are announced by their owners or submitted directly to FW Dodge. Project progress is tracked up to the time of award of prime construction contracts and subcontracts, after which the project is removed from the active database. FW Dodge sells the project information to material, equipment, and service providers who then offer their services and products. The FW Dodge database is widely used in the construction industry. FW Dodge maintains satellite offices in every major city in the US, with a reading room for contractors to review project plans and specifications. In a typical calendar year more than 400, 000 projects in the US may be listed in some stage of planning, design, or construction. FW Dodge also tracks overseas and foreign projects. The study was limited to projects within the United States.

The FW Dodge database did not have the required detailed information on each project for this study. The data collected by FW Dodge that was useful to this study was as follows:

- Project identification
- Addresses and points of contact for the owner or the project manager
- Construction industry sector and type of facility
- Approximate dollar cost of the project
- Location of the project

The sampling frame was derived by applying filter criteria to the database for location, stage of completion, project type, and project value. The filter for *location* was set to eliminate projects outside the US. The filter criterion for *completion stage* was set to eliminate projects not scheduled to complete construction prior to the survey distribution. The filter criterion for *project type* was set to select projects only in the building, horizontal and utilities sectors. The filter criterion for *project value* was set to include projects less than $50 million and greater than $3 million. Applying the above filters yielded a sample frame of 942 projects, from which a random sample of 200 projects was extracted. As expected, the return rate from the survey was low, requiring a chi-squared test for goodness-of-fit to determine if the return were representative of the population [24, 39].

Instruments

This study gathered data utilizing a survey instrument especially designed for the study. The survey instrument was in the form of a matrix, normal for gathering technical information [24, 45, 66]. Each survey form was marked with a handwritten code that linked it to one copy of the project's data sheet, also marked with the same code. The code allowed the respondent to be contacted for any necessary clarification or omissions on the returned form. Once the data on the returned instrument were verified, the coded project data sheet was destroyed, so that no direct linkage to the project database existed.

The complete survey package consisted of a cover letter, FW Dodge report specific to the recipient, survey instructions, and a pre-addressed, stamped, return envelope. The survey instrument had four parts, printed back to back on a single sheet of 8-$^{1}/_{2}$" by 11" paper. Part 1 gathered information as to how the project was contracted, i.e., how each phase of the project was executed by prime contracts. Part 2 gathered information on how the contractors were selected, i.e., by qualifications, price or a combination. Part 3 gathered information on original and final contract price and duration. Part 4 gathered information on contract cost and time growth for each contract modification. The survey instrument is presented in Appendix C.

Part 1 -Project Organization. Part 1 identified in a pre-printed list several separate phases that might be contracted out by the owner as prime contracts. The purpose of Part 1 was to identify if a project phase, particularly design, was executed by the owner, by a prime contract, or by a combination of both. The following phases, if contracted, would typically be performed by an AE firm:

- Project management
- Planning
- Geo-technical investigation
- Design
- Construction management

The construction phase could be executed by more than one construction contractor.

Part 2 - Contract Award Criteria. The purpose of Part 2 was to determine whether an AE firm was selected by QBS procedures or non-QBS procedures without employing 'QBS' terminology. Two columns determined this: the column under the sub-heading "*Qualifications Process*" titled "*Qualification evaluated separately from price*"; and the column under the sub-heading "*Price Determination*" titled "*Price negotiated after selection*." An 'x' in both columns was conclusive that QBS procedures were used. An 'x' only in the later column was indicative that QBS procedures were used. If both columns were blank, the selection process must have been non-QBS.

Part 3 - Contract Cost and Duration. The information in the columns titled "*Original Contract Amount*" and "*Original Contract Duration*" was necessary to be able to reduce cost growth and time growth for construction contracts to a percentage or ratio. The information in the columns titled "*Final Contract Amount*" and "*Final Contract Duration*" was a check on whether contract cost or time growth occurred.

Part 4 - Prime Construction Contract Modifications. The purpose of Part 4 was to gather information on construction contract modifications that were partially or wholly the fault of an AE firm's failure to adequately perform a contractual responsibility, including design errors and omissions. If a percentage was placed under the columnar heading "*Root Causes of Construction Modifications or Project Change*" and the subheading "*Non-performance of Another's Contractual Responsibility*" for any of the following phases, fault of an AE firm was indicated:

- Project Manager
- Geo-technical investigation (Geotech)
- Designer
- Construction manager

For such modifications, contract cost and time growth data was collected under the columnar headings "*Phase/Contract Cost Impact*", and "*Phase/Contract Time impact.*"

Procedures

Outline. The procedures followed in this study were performed according to the following outline:

1. The database of the population of projects to be considered was developed.
    a. The sample frame (the study population) was established.
    b. A random sample of projects was extracted from the sample frame.
2. The survey instrument was validated as follows.
    a. A trial sample of 10 projects was extracted from the sample.
    b. The survey instrument was mailed out to the trial sample.
    c. Follow-ups were made with telephone calls and reminder postcards.
    d. The trial sample returns were evaluated.
    e. The survey instrument did not require any alterations.
3. The validated survey instrument was mailed out to the sample.
    a. Follow-ups were made with telephone calls and reminder postcards.

4. The returns were evaluated for obvious errors and omissions of essential data.
    a. Any unclear or missing essential data was clarified with the participant.

5. A chi-squared test for goodness-of-fit was performed on the returned projects to evaluate any self-selection bias due to low return rates.

6. The data was prepared as follows:
    a. The relevant data from the returned survey instruments were extracted.
    b. The data was sorted into categories -- QBS, non-QBS, and owner-designed.
    c. The raw data for contract cost and time growth was reduced to a factor.
    d. The reduced data set was proofed for errors or omissions.
    e. Any documentation linking the study participants to the data was destroyed.

7. The data was analyzed.
    a. The owner-designed category was excluded, as no AE relation existed.
    b. One-way ANOVA was used to compare categories QBS and non-QBS.
    c. Efficiency and indicated legislative action were determined using Tables 2 through 4 in Section 4.

8. The results were reported herein.
    a. No data was presented that allowed the identification of survey participants
        1) Specific project cost were reported by letter codes I through M.
        2) Construction contract costs and durations were reported only as aggregated amounts.
        3) Cost and time growth factors for all construction contracts were calculated by Equation 1, below. AE cost and time growth for a construction contract was aggregated from all modifications to the construction contract. Construction contracts with no AE cost or time growth would have a growth factor of exactly 1:

Equation 1)

$$\textit{growth factor} = 1 + \frac{\textit{construction contract growth due to AE fault}}{\textit{original construction contract value}}$$

Analysis Procedures. The primary research question was whether cost or time growth caused by QBS selected AE firms was significantly different from cost or time growth caused by non-QBS selected AE firms. QBS legislation implicitly assumes the difference is significant. This study tested significance using ANOVA procedure, using the letter 'Q' to represent the set of *QBS*-related cost or time growth data, and the letter 'N' to represent the set of *non-QBS*-related cost or time growth data. The primary research question was stated as follows:

Are proposed categories 'Q' and 'N' significantly different statistically?

The primary research question gave rise to two hypotheses--the primary hypothesis, H_1, and the null hypothesis, H_0, stated symbolically as follows:

H_0: Q = N
H_1: Q ≠ N

A secondary research question was whether the direction of the difference was positive or negative. QBS legislation implicitly assumes that the direction is positive. The direction would have been determined by subtracting the mean value of set 'Q' from the mean value of set 'N', if the results of the ANOVA were significant. A direction would have been determined for cost growth and time growth separately. The secondary research question was stated as follows:

Is the mean value of set N minus the mean value of set Q greater than zero?

The secondary research question gave rise to the second hypothesis, H_2, stated symbolically as follows:

H_2: $(\mu_N - \mu_Q) > 0$

A tertiary research question would rise if the ANOVA results were significant, which was whether the *strength*, or *importance,* of the difference between sets 'Q' and 'N' was substantial. QBS legislation implicitly assumes that the strength is substantial. Strength would have been calculated as E^2, determined for cost and time growth separately, by dividing the explained sum of the squares by the total sum of the squares from the ANOVA calculations. The tertiary research question was stated as follows:

Is the strength of the difference between Q and N substantial?

The tertiary research question gave rise to the third hypothesis, H_3, stated symbolically as follows:

H_3: $E^2 >> 0$

Table 1. Research Hypotheses

Research Question	**Hypothesis**	
	Cost growth	**Time Growth**
Primary	H_{0c}: $Q_c = N_c$	H_{0t}: $Q_t = N_t$
	H_{1c}: $Q_c \neq N_c$	H_{1t}: $Q_t \neq N_t$
Secondary	H_{2c}: $(\mu_{Nc} - \mu_{Qc}) > 0$	H_{2t}: $(\mu_{Nt} - \mu_{Qt}) > 0$
Tertiary	H_{3c}: $E_c^2 >> 0$	H_{3t}: $E_t^2 >> 0$

The research questions and their resultant hypothesis were summarized in Table 1, above. The subscripts 'c' and 't' denote the sets of cost and time data respectively, and 'μ' denotes the mean of the set.

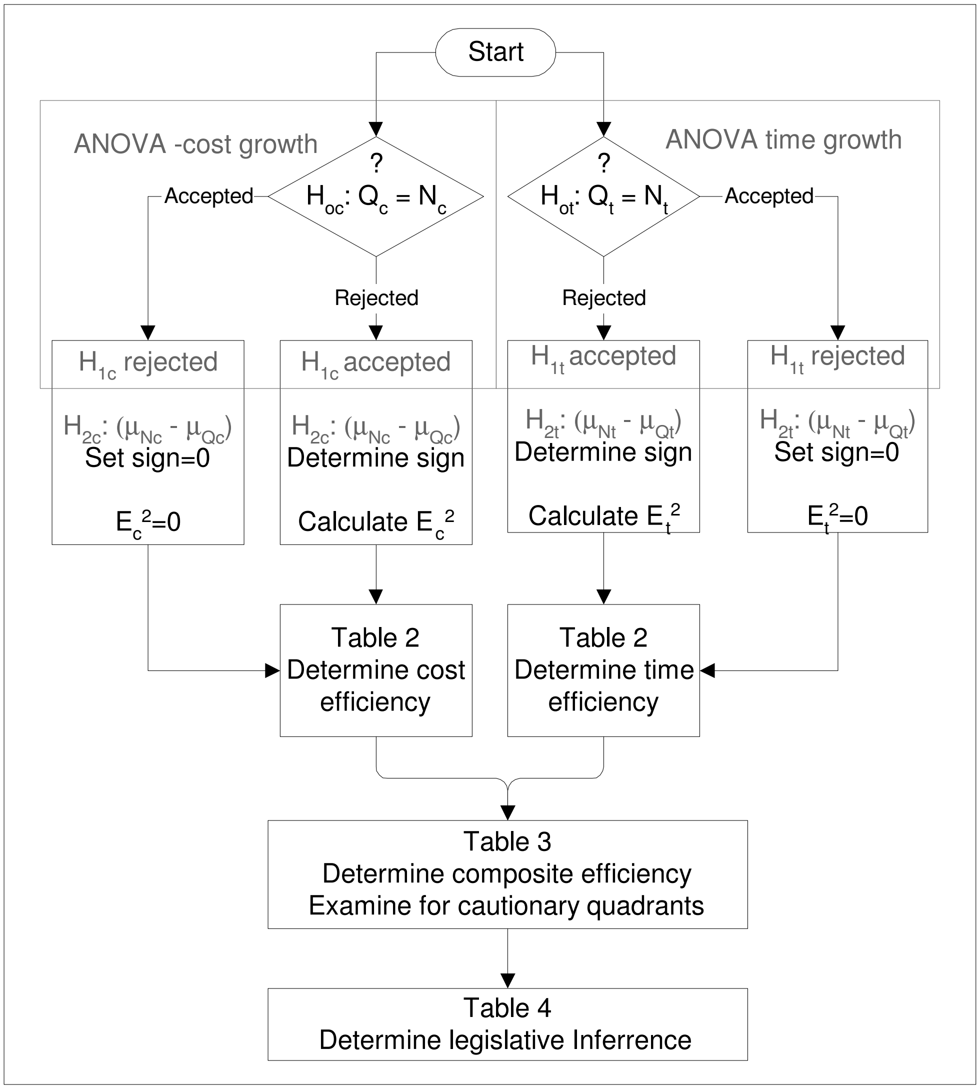

Figure 2. Analysis Flowchart

The research hypotheses in Table 1 gave rise to tests that were performed in the order set forth in Figure 2 - Analysis Flowchart, above. ANOVA was performed on cost growth and time growth separately. The output of each ANOVA would be a sign determined from (μ_N-μ_Q), and the value of E^2. If the null hypothesis was accepted (H_0: Q=N), then the sign would be set to zero (μ_N-μ_Q=0), and E^2 would also be set to zero (E^2=0). The sign and E^2 would then be input to Table 2, below, to determine the efficiency, *e*.

Table 2. Efficiency

$(\mu_N - \mu_Q)$	E^2	*e*
+	$\geq$ .5	**+++**
+	.2 to .5$^-$	**++**
+	0^+ to .2	**+**
0	0	**0**
-	0^+ to .2	**-**
-	.2 to .5$^-$	**- -**
-	$\geq$ .5	**- - -**

In Table 2 *efficiency*, *e*, was a relative value rather than a numerical score. Three plusses were relatively thrice as good as one plus, and two pluses twice as good as one. Conversely, three negatives were relatively thrice as bad as one negative. The ranges for E^2 in Table 2 were set assuming that random chance and unknown factors would still be a significant portion of the total variance--that is, E^2 should not be expected much above 0.5. Once *e* had been determined for cost growth and for time growth, they were input to table 3, below, to obtain a composite efficiency.

Table 3 merely aggregated the plusses and minuses from cost growth and time growth efficiencies, allowing plusses and minuses to cancel each other on a one-to-one basis when signs were opposite. When the aggregation was all plusses or all minuses no particular concern would be necessary for the relative value of the efficiencies of cost growth to time growth. Tables 3 assumed the relative efficiencies from cost growth were comparable to those from time growth.

Table 3. Composite Efficiency

Cost growth efficiency e_c	Time growth efficiency, e_t: +++	++	+	0	–	– –	– – –
+++	++++++	+++++	++++	+++	++	+	=
++	+++++	++++	+++	++	+	=	–
+	++++	+++	++	+	=	–	– –
0	+++	++	+	0	–	– –	– – – -
–	++	+	=	–	– –	– – –	– – – –
– –	+	=	–	– –	– – –	– – – –	– – – – –
– – –	=	–	– –	– – –	– – – –	– – – – –	– – – – – –

CAUTION, opposite signs -- relative weighting not determined

However, the dollar value of time growth could vary greatly between projects and between owners, depending on expected return-on-investment rates for commercial projects, or cost-benefit ratios for public projects. Public projects were generally expected to value cost efficiency higher than time efficiency, while for commercial projects the reverse can be expected. Therefore, Table 3 had a cautionary range shaded in gray to highlight that when cost efficiency and time efficiency were oppositely signed, the resultant was merely indicative and not conclusive.

Table 4. Indicated Legislative Action

Efficiency description	Composite efficiency score	Recommendation for QBS legislative action
Very efficient	≥ +++	**Strengthen**
Efficient	++	**Retain** as is
Weakly efficient	+	**Revise** or revoke
Not efficient	0	**Revoke** entirely
efficiencies = inefficiencies	=	**Revise** to eliminate inefficiencies
Weakly inefficient	-	**Revoke** or revise
Inefficient	- -	**Revoke** entirely
Very inefficient	≤ - - -	**Revoke** entirely

The results from Table 3 were input to Table 4, above, to obtain the QBS legislative recommendation. Table 4 had only four basic recommendations as outcome: strengthen, retain, revise, or revoke existing QBS legislation. *Strengthen* implied that existing QBS procedures were very efficient, and consideration should be given to strengthen the requirement to use them and/or broaden their application. *Retain-as-is* implied that existing QBS procedures were efficient enough to retain, but not efficient enough to consider strengthening. *Revise* implied some remnants of the existing legislation might be salvageable by narrowing their application, or eliminating factors that contribute to inefficiency. Revoke implied that existing QBS procedures were not sufficiently efficient at best, or inefficient at worse, and should be scrapped.

Inferring causality. In order for the research results to legitimately influence QBS legislation, causality should be strongly inferred between the legislative intent and the proposed study results. Graziano [40] set three criteria to conclude causality:

1) Statistical significance (elimination of random chance)
2) Elimination of confounding factors (spuriousness)
3) Demonstration that the independent event affects the dependent event in the predicted manner (manipulation of variables.)

The ANOVA procedures satisfied the first criterion. The second criterion was satisfied by the design of the study directly identifying root causes of contract cost and time growth. The third criterion required manipulation of the variables, which was not directly feasible, hence the quasi-experimental nature of the research. Nevertheless, causality was still strongly inferred because the causal path had been clearly defined, known confounding factors identified and controlled, and the essential element of timing (the independent event preceded the dependent event in time) was satisfied [29].

Significant confounding factors were eliminated because the construction project process was a repeatable and definable process. Contractual instruments specified assignment of risk, responsibility and reward. Even when consequences of mal-performance were contractually deflected, they could still be identified. A causal chain for construction contract cost and time growth attributable to AE malfeasance was directly separated from all other causes spurious to the research question.

In this study causality was strongly inferred for construction contract cost growth because all known confounding factors contributing to such growth were identified and removed. However, causality might be less strongly inferred for construction contract time growth because of the following two conditions:

1) the *project* schedule could not be analyzed or assessed for those projects consisting of multiple, simultaneous construction contracts, so no determination could be made if *contract* completion delay might have impacted *project* completion, and

2) the appropriate weighting of time efficiency against cost efficiency was not applicable for the results obtained, but could be a factor if the signs were opposite.

SECTION FOUR

RESULTS

Description of the Sample

Survey Instrument Trial. Ten randomly selected projects from the sample were used to validate the survey instrument. Five of the trial survey requests were mailed, and five were transmitted by facsimile (fax). Of the five mailed, with follow-up, reminder post cards, only one was returned. Of the five faxed survey requests, only one recipient took time to answer the questionnaire. Surprisingly, fax transmission with voice telephone follow-up proved to be both costly and disappointingly difficult, primarily because proceeding beyond an answering machine required many long-distance calls, long waits holding, and even then the proper person was generally unavailable. The two returns that were received indicated no particular problems and no alterations were made to the survey instrument.

Sample. Of the 200 survey requests sent out (including the 10 in the trial run) 55 were returned because the addressee had moved and left no forwarding address, 13 were politely refused because the respondents were too busy, 3 were returned because the projects were cancelled, 1 return had insufficient data to be useful and no contact information, 23 returns with completed data were received, and the remaining requests were never heard from despite three follow-up postcards. Such low return rates are not uncommon for mail-in surveys [24, 39], and a chi-squared goodness-of-fit test taken from Spiegel [65] (p.218-219) was used, as described below.

The predominant known characteristic of the sample (and by inference the population) was the project cost estimate, represented by a letter code having the cost ranges defined in Table 5, below. Of the 200-project sample, 33, (16.5%) had only letter codes for cost estimates.

Table 5. Project Cost Code

Letter Code	Cost Range, $ millions	
	Lower Limit	Upper Limit
	≥	<
M	25	50
L	15	25
K	10	15
J	5	10
I	3	5

In the column labeled "Random" in Table 6, below, are the frequencies of the sample for each letter code cost estimate.

Table 6. Sample Frequency Distribution

Frequency Distribution		
Cost Code	Sample	Expected
M	14	1.54
L	17	1.87
K	18	1.98
J	72	7.92
I	79	8.69
n	200	22

The letter cost-codes in Tables 5 and 6 were arranged contiguously, and thus fairly represent a discretized probability density function that could be used to determine the expected frequency for any 'n.' In the column of Table 6 labeled "Expected" is the frequency distribution for n = 22, obtained by proportioning the sample 'n' to the return 'n.

These expected frequencies were compared against the frequency distribution for the returns.

Table 7, below presents the value for the chi-square goodness-of-fit calculated between the frequency distribution of the returns and those of the expected frequency distribution of the same n, determined from the sample in table 6, above.

Table 7. Chi-squared Goodness-of-Fit

		Frequencies			
		Returns	**Expected**		
	i	f_R	f_E	$(f_R - f_E)^2 / f_E$	
	1	2	1.54	0.137	
	2	2	1.87	0.009	
	3	3	1.98	0.525	
	4	8	7.92	0.001	
k	5	7	8.69	0.329	
	n	22	22	1.001	χ^2
ν = degrees of freedom				$\Sigma\ (f_R - f_E)^2 / f_E$	
$\nu = k - 1 - m$, $m = 2$				5.99	χ^2_{95}
$\nu = 5 - 1 - 2 = 2$				.103	χ^2_{05}

In Table 7, above, 'm' is the additional degrees of freedom lost. One degree was lost because the sample rather than the population was used to determine expected frequencies, and one degree because the discrete values were used directly instead of determining a theoretical probability density function.

For the chi-squared goodness-of-fit test, the chi-squared value was compared to a critical value, χ^2_{95}, for two degrees of freedom, which was equivalent to the $\alpha = 0.05$ level of significance. The null hypothesis, H_0, for this test was that the frequency distributions were not significantly different, or H_0: $\chi 2 < \chi^2_{95}$ (the fit is good), which was the result obtained in Table 7.. In addition, since H_0 was not rejected, a test was made to determine if the fit was so good as to be incredible. This was determined by comparing χ^2 and χ^2_{05} for two degrees of freedom, which was equivalent to the $\alpha = 0.95$ level of significance. If $\chi^2 < \chi^2_{05}$ then concern would exist that the fit might be too good to be credible. The result obtained in Table 7 was that $\chi^2 > \chi^2_{05}$, assuring that the fit is not so good as to be incredible. Thus the chi-squared goodness of fit test established that the survey returns were reasonably representative of the population.

While the chi-squared goodness-of-fit test as performed above provided assurance that the returns were reasonably representative of the population as regards the frequencies associated with project cost code, it is prudent to emphasize that such test was only approximate for the study for two reasons:

1) *Project cost code* was a proxy--used because the frequency distributions of the study parameters, namely *construction contract cost and time growth*, were unknown in both the population and the sample. Such information was not available from the FW Dodge database and could only be obtained from actual survey returns. Thus, a major assumption remains unverified--that the proxy (project cost code) adequately represents the study parameters (construction contract cost and time growth.)

2) A theoretical probability distribution was not determined for the sample project cost code frequencies because of the broadband nature of the cost code itself (e.g., $25 million $\leq$ M < $50 million) --no increase in accuracy could reasonably be assumed. The consequence of directly utilizing the discrete values was assumed as the loss of one additional degree of freedom.

Returns. The important frequency distributions of the completed survey returns are summarized in Table 8, below.

Table 8. Completed Survey Return Frequencies

n	Frequency					n	
O+N+Q	O	N_B	N_V	N	Q	N+Q	Classification
23	3	1	7	7	13	20	Projects responding
31	0	1	8	9	22	31	AE contracts
35	3	1	12	13	19	32	Construction contracts
212	20	1	17	18	174	192	Construction contract modifications
18	3 *	0	4	4	11	15	AE-related construction contract modifications

Where O = Projects with 100% owner-performed design
N_B = Projects with AE firm selected by bidding (price only)
N_V = Projects with AE firm selected by best-value procedures (price and qualifications)
Q = Projects with AE firm selected by QBS procedures (qualifications only)
N = N_B + N_V = Projects with AE firm selected by non-QBS procedures
* 100% owner-designed

Noteworthy from Table 8, above was the breakout of the N category (non-QBS) by *bidding* (N_B) and *best value* (N_V). Only one small AE contract (a geo-technical AE firm) was reported as selected by *bidding* (price only), with all the other AE firms in the N category selected by *best-value*, using a combination of qualifications and price. This was both surprising and important, indicating that straight bidding (price only) selection procedures were very infrequently applied to AE firms, and that the study conclusions may not be applicable to such bidding-only situations--one occurrence being insufficient to make meaningful generalizations about bidding.

Table 9, below was derived from Table 8 above. These two tables provided possible population characteristics more related to the study interests than can be gleaned from the FW Dodge reports, and are of probable interest to follow-on studies.

Table 9. Completed Survey Return Frequency Ratios

O+N+Q	O	N_B	N_V	N	Q	N+Q	Classification
1.35	0	1	1.14	1.29	1.69	1.55	AE contracts / project
1.52	1	1	1.71	1.86	1.46	1.60	Construction contracts / project
9.22	6.67	1	2.43	2.57	13.38	9.60	Construction contract modifications / project
6.06	6.67	1	1.42	1.38	9.16	6.00	Construction contract modifications / construction contract
0.78	1*	0	0.57	0.57	0.85	0.75	AE-related construction contract modifications / project
0.51	1*	0	0.33	0.31	0.58	0.47	AE-related construction contract modifications / construction contracts
0.08	0.15*	0	0.24	0.22	0.06	0.08	AE-related construction contract modifications / construction contract modifications

Where O = Projects with 100% owner-performed design
N_B = Projects with AE firm selected by bidding (price only)
N_V = Projects with AE firm selected by best-value procedures (price and qualifications)
Q = Projects with AE firm selected by QBS procedures (qualifications only)
N = N_B + N_V = Projects with AE firm selected by non-QBS procedures
* 100% owner-designed

Referring to Table 8 and 9, above the following frequency relations are noteworthy:

1) Of the 23 projects returned (O+N+Q), 3 (13%) were designed by owners without any AE firm involvement. These 3 owner-designed projects were necessarily excluded from the study, as no AE firm was involved.

2) Of the 20 remaining projects (N+Q) included in this study, there were 31 AE firms and 32 construction contractors involved as prime contracts, yielding an average ratio of 1.0 AE firms per construction contract, and 1.6 construction contracts per project. One could infer from these ratios that multiple AE firms per project occurred infrequently, while multiple construction contracts per project occurred frequently.

3) Category N had 13 construction contracts with 18 modifications, for an average of 1.4 modifications per construction contract. Category Q had 19 construction contracts with 174 modifications, for an average of 9.2 modifications per construction contract.

However, 5 construction contracts, from 5 different projects in category Q, accounted for 148 of the modifications, for an average of 30 modifications per construction contracts.

4) Category N had 4 AE-related construction contract modifications out of 18 total construction contract modifications, or 22%, while category Q had 11 out of 174, or 6%.

Table 10, below provides aggregate dollar information from the survey returns. Specific pricing on contracts and modifications was not presented in order to preserve the anonymity of the survey participants.

Table 10. Aggregated Costs, $ million

O+N+Q	O	N_B	N_V	N	Q	N+Q	Category
203.16	16.57	0.27	46.92	47.20	139.40	186.60	Construction contracts
20.16	0.63	0.15	2.99	3.13	16.39	19.53	Construction contract modifications
2.63	0.11	0	0.53	0.53	1.99	2.52	AE-related construction contract modifications

Where O = Projects with 100% owner-performed design
N_B = Projects with AE firm selected by bidding (price only)
N_V = Projects with AE firm selected by best-value procedures (price and qualifications)
Q = Projects with AE firm selected by QBS procedures (qualifications only)
N = N_B + N_V = Projects with AE firm selected by non-QBS procedures
* 100% owner-designed

Table 11, below, provides percentages of the aggregate dollar information from Table 10, above.

Table 11. Aggregated Costs, Percentages

O+N+Q	O	N_B	N_V	N	Q	N+Q	Category
9.9%	3.8%	53.4%	6.4%	6.6%	11.8%	10.5%	Construction contract modifications / construction contracts
1.3%	0.6%	0.0%	1.1%	1.1%	1.4%	1.4%	AE-related construction contract modifications / Construction contracts
13.0%	16.7%	0.0%	17.6%	16.8%	12.2%	12.9%	AE-related construction contract modifications / construction contract modifications

See Table 9 for definition of terms

Research Question

Cost growth results. Table 12, below presents the cost growth factors calculated according to Equation 1, represented by X_{ij}, and the ANOVA sum- of-squares solution for an unequal number of observations.

Table 12. ANOVA Sum of Squares for Cost Growth

	X_{ij}		X_{ij}^2		
	Non-QBS	**QBS**	**Non-QBS**	**QBS**	
i j →	1	2	1	2	
1	1	1	1	1	
2	1	1.014	1	1.027	
3	1	1	1	1	
4	1	1.032	1	1.065	
5	1	1	1	1	
6	1.026	1.002	1.053	1.005	
7	1	0.995	1	0.989	
8	1	1.000	1	1.001	
9	1.003	1.001	1.006	1.002	
10	1	1	1	1	
11	1.028	1	1.058	1	
12	1.036	1	1.074	1	
13	1	1	1	1	
14		1		1	
15		1.280		1.638	
16		1.007		1.013	
17		1.006		1.012	
18		1.028		1.056	
19		1.009		1.018	
n_j	13	19	13.191	19.827	$= (\Sigma X_i^2)_j$
$\tau_j = (\Sigma X_i)_j =$	13.094	19.373			
$M_j = \tau_j / n_j =$	1.007	1.020			
$\tau_j^2/n_j =$	13.189	19.754			
$SD_j =$	0.0134	0.0638			

$n = \Sigma n_j =$	**32**	$\Sigma(\Sigma X_i^2)_j =$	**33.018**
$\tau = \Sigma \tau_j =$	**32.467**		
$M_{Grand} = \tau/N =$	1.015		
$\tau^2/n =$	**32.941**	$v_c = \Sigma(\Sigma X_i^2)_j - \tau^2/n =$	**0.077**
$v_{cB} = \Sigma(\tau_j^2/n_j) - t^2/n =$	**0.001**	$v_{cW} = v - v_B =$	**0.075**

Table 13, below, completed the ANOVA solution for cost growth with the F-test for significance, using the sum-of-squares calculated in Table 12.

Table 13. ANOVA F-Test for Cost Growth Factor

Degrees of Freedom					
k =	2				
ν_1 = k-1 =	2 - 1	=	1		
ν_2 = n-k =	32 - 2	=	30		
F_{data} =	$\frac{v_{cB}/\nu_1}{V_{cW}/\nu_2}$	**=**	$\frac{.001 / 1}{.075 / 29}$	**=**	**0.47**
Significance					
α	**0.05**	**0.01**			
$F_{critical}$ = $F_{1, 30}$	4.17/	7.56	F Distribution Table		
F_{data}>$F_{critical}$?	No	No			
H_{co}	**Accept**	**Accept**	**H_0:** Non-QBS cost growth = QBS cost growth		

The conclusion from Table 13 was that no significant difference exited between Non-QBS and QBS cost growth caused by an AE. Therefore, the following values were set equal to zero:

$E_c^2 = v_{cB} / v_c = 0.02 \equiv 0$, and

$Sign_c$ from $(\mu_{cN}-\mu_{cQ}) \equiv 0$

The above zero values for E_c^2 and the $sign_c$ were input to Table 2, yielding a cost efficiency, e_c, equal to zero, and the interpretation that QBS procedures were not efficient as regards to cost growth.

Time growth results. Table 14, below presents the time growth factors calculated according to Equation 1, represented by X_{ij}, and the ANOVA sum- of-squares solution for an unequal number of observations.

Table 14. ANOVA Sum of Squares for Time Growth

	X_{ij}		X_{ij}^2		
	Non-QBS	QBS	Non-QBS	QBS	
i j →	1	2	1	2	
1	1	1	1	1	
2	1	1	1	1	
3	1	1	1	1	
4	1	1.038	1	1.076	
5	1	1	1	1	
6	1.041	1.003	1.084	1.007	
7	1	1.017	1	1.034	
8	1	1	1	1	
9	1.047	1	1.096	1	
10	1	1	1	1	
11	1	1	1	1	
12	1	1	1	1	
13	1	1	1	1	
14		1		1	
15		1.068		1.140	
16		1.021		1.043	
17		1.000		1.000	
18		1.021		1.043	
19		1.057		1.117	
n_j	13	19	13.180	19.461	$= (\Sigma X_i^2)_j$
$\tau_j = (\Sigma X_i)_j =$	13.088	19.225			
$M_j = \tau_j / n_j =$	1.007	1.012			
$\tau_j^2/n_j =$	13.177	19.453			
$SD_j =$	0.0166	0.0208			
$n = \Sigma n_j =$	32		$\Sigma(\Sigma X_i^2)_j =$ 32.641		
$\tau = \Sigma \tau_j =$	32.313				
$M_{Grand} = \tau/N =$	1.010				
$\tau^2/n =$	32.629		$v_t = \Sigma(\Sigma X_i^2)_j - \tau^2/n =$ 0.011		
$v_{tB} = \Sigma(\tau_j^2/n_j) - t^2/n =$		0.0002	$v_{tW} = v - v_B =$ 0.011		

Table 15, below, completed the ANOVA solution for time growth with the F-test for significance, using the sum-of-squares calculated in Table 14.

Table 15. ANOVA F-Test for Time Growth Factor

Degrees of Freedom					
k =	2				
ν_1 = k-1 =	2 - 1	=	1		
ν_2 = n-k =	32 - 2	=	30		
F_{data} =	$\frac{\nu_{tB}/\nu_1}{\nu_{tW}/\nu_2}$	**=**	$\frac{.0002 / 1}{.011 / 29}$	**=**	**0.54**
Significance					
α	**0.05**	**0.01**			
$F_{critical}$ = $F_{1, 30}$	4.17	7.56	F Distribution Table		
F_{data}>$F_{critical}$?	No	No			
H_{to}	**Accept**	**Accept**	**H_{t0}:** Non-QBS time growth = QBS time growth		

The conclusion from Table 15 was that no significant difference existed between Non-QBS and QBS time growth caused by an AE. Therefore, the following values were set equal to zero:

$E_t^2 = v_{tB} / v_t = 0.02 \equiv 0$, and

$Sign_t$ from $(\mu_{tN}-\mu_{tQ}) \equiv 0$

The above zero values for E_t^2 and the $sign_t$ were input to Table 2, yielding a time growth efficiency, e_t, equal to zero, and the interpretation that QBS procedures were not efficient as regards to time growth.

Composite efficiency. The above results, $e_c = 0$ and $e_t = 0$, were input to Table 3, yielding a composite efficiency, e, equal to zero, and the interpretation that QBS procedures were not efficient as regards to both cost and time growth.

Indicated legislative action. The composite efficiency, $e = 0$, was input to Table 4, yielding an indicated legislative action to revoke QBS legislation entirely.

SECTION 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Literature search. While published opinions on QBS issues were abundant, only one prior study with data was found--the results of which were not applicable to this research, and which also were considered inconclusive. The research was therefore groundbreaking.

Methodology. Survey research methodology was employed to gather data. The survey instrument was a self-administered, mail-in questionnaire. A 200-project sample was randomly extracted from a sample frame (study population) of 942 construction projects at or nearing completion in the building, utilities and horizontal construction-industry sectors. Twenty-three completed project questionnaires were returned, yielding 32 construction contracts for analysis. Concerns for any self-selection bias introduced by the low response rate was addressed by performing a chi-squared goodness-of fit test, the results of which provided reasonable confidence that the returns were representative of the sample frame. Standard ANOVA statistical procedures were employed to compare QBS and non-QBS categories for both cost and time growth.

Research Question. The results of this research were as follows:

Primary. No significant difference due to AE fault was found between the QBS and non-QBS categories for either cost growth or time growth.

Secondary & Tertiary. As a consequence, the sign of the relation was by definition set equal to zero, and the strength of the relation, measured by E^2, was also set equal to zero. These consequential results determined values for efficiency, *e*, equal to zero for cost growth, time growth and the composite of both.

Conclusions

One might be moved to ask just how strong a case the results summarized above imply, and to what end. The answer to how strong a case the results make lies separately in three very different disciplines--the *research process* itself, the *construction industry model* employed, and the *political arena*.

The research process. The research methodology employed was standard and straightforward. This research study had a limited budget, and funds available dictated the scope of the effort and methodology chosen--in this case a self-administered mail-in survey. The consequences of financial constraints were a limited sample frame, and the expected low rate of response.

Table 16. Survey Methods and Costs

Survey Method	Data Quality	Response Rate	Rough Estimate for this survey
Personal interview	High	High	\$100,000 - \$200,000
Telephone Interview	Mixed	Mixed	\$10,000 - \$20,000
Mail-in survey,	Moderate	Low	\$1,000 - \$2,000

NOTE: Labor costs not included

Improving the research process would entail substantial increased costs. An example of typical survey choices for this study were as presented in Table 16, above, which highlight the main drawback of improving the research process--greatly increased cost. Table 16 does not include the cost of labor. Labor costs would increase the estimate an order of magnitude.

The construction industry model. Great care was taken in this study to adequately define the construction model. While the FW Dodge database was indispensable to this study, in and of itself, it was inadequate to fully characterize the population of completed construction projects. This is not to fault FW Dodge, as their effort is driven by economics--there is waning commercial value for information about a construction project once it is under construction, and little if any after it is completed. Lacking direct information on the distribution of AE firms, construction contracts and construction contract modifications in the population of completed projects, or even in the sample, it was necessary to employ a proxy (project cost code) in evaluating how representative the returns were. Such use of proxies is a practical necessity in some research, and is not unusual. Generalizing the research findings to the population frame was warranted by the results of the chi-squared goodness-of-fit test. Nevertheless, improvement in the construction model, or at least faith in it, could be improved by the establishment of a comprehensive database on completed construction projects.

The political arena. The casual observer of political processes might wonder if any logic or discipline other than popularity or whim exists in government policy-making. Legislatures and regulating agencies, however, do appear to take very considered approaches to enacting laws and regulation. Their largest failure would seem not to lie in lengthy deliberations of merit, but a failure to *measure* efficacy, preferably before, and certainly after making laws and regulations.

This pervasive *failure to measure* inspired in large part the undertaking of this research. The efficacy of every law and regulation should be established--and if, as in this case, found wanting--should be revised, abandoned, or revoked. Unless policy is affected, research findings, such as this instant one, remain academic and of little practical meaning.

Recommendations

Follow-on research. The foremost recommendation is the standard scientific requirement of independent verification. The literature search suggests this research is groundbreaking, and thus follow-on, independent, confirmatory research is highly desirable.

The second recommendation is to widen the scope of future investigations. The results of this research were decisive and clear--QBS procedures were not efficient--they did not provide significantly different results for construction cost or time growth for the construction industry sectors sampled. However, other important sectors covered by QBS regulation were not investigated, and could provide different results. Moreover, a sizable number of projects were excluded-- the few projects with cost estimates greater than $50 million, and the very-numerous projects with cost estimates less than $3 million. It is possible that QBS procedures provide significant benefit for complex, high-cost projects, and possibly negative benefits for simple, low-cost projects--or vice versa.

The third recommendation is to increase the number of data points so that analysis by sector is possible. This research had insufficient returns to investigate sector differences with any confidence. It is possible that QBS procedures affect construction industry sectors differently. The number of data points could be increased by increasing the return rate, expanding the sample size, adopting different survey techniques, or a combination of these.

The fourth recommendation concerns funding future research. All of the above recommendations are likely to entail significant funding requirements. Proponents of QBS and government agencies having oversight on QBS compliance should fund future research and conclusively establish the efficacy of QBS procedures.

Policy. While not conclusively established in this research, it appears that QBS procedures result in higher design costs than non-QBS procedures--without commensurate benefit to the public. Legislation was promulgated at both the federal and state level making QBS procedures mandatory, with sanctions and penalties for non-compliance. These sanctions and penalties make the acquisition of unbiased data difficult--requiring great care in choosing appropriate vocabulary and measures to protect the identity of projects and owners in non-compliance. The efficacy of QBS procedures has now been cast in doubt by the findings of this instant research. At the very least, sanctions and penalties for non-compliance should be suspended until further confirmatory research provides justification for them.

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   Synopsis: An AIA workbook for members on how to promote QBS methods in small, inexperienced government departments and local boards seeking design services.

3. AIA. 1994. How the federal government selects architecture / engineering firms. Washington, DC. American Institute of Architects.

   Synopsis: A layman's restatement of the Brook's act.

4. AIA. 1996. Federal legislative priorities - public policy bulletin. American Institute of Architects. Jan

   Synopsis: A handout bulletin supporting the Brooks Act which established QBS procurement procedures for federal projects. Identifies COFPAES as the lobbying arm of AIA and other Engineering Organizations.

5. ACEC. (Unpublished). Survey of state QBS laws and registration boards. Washington, DC. American Consulting Engineers Council. Furnished via e-mail 7 Feb 2000.

   Synopsis: A matrix of states with QBS AE selection procedures in place, with limitations.

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13. Institute of Electrical and Electronic Engineers (IEEE). Internet web site. http:\\www.ieee.org. Accessed 10 April 2000.

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15. American Society of Landscape Architects (ASLA). Internet web site. http:\\www.asla.org. Accessed 6 Feb 2000.

16. American Society of Mechanical Engineers (ASME). Internet web site. http:\\www.asme.org. Accessed 31 Jan 2000.

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    Synopsis: Review of publication cited in reference 23, above.

18. APWA. 1994. Policy statement: architect/engineer selection. Wash. DC. American Public Works Association, 19 Aug 94.

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    Synopsis: an editorial supporting the Brook's Act.

20. (Author/editor not identified). Editorial: what's architect worth? Architectural Record, Mar 94 page 9.

    Synopsis: an editorial supporting the Brook's Act.

21. (Author not identified). Procurement: Ohio designers fighting price-based selection. ENR 7 Oct 91 page 11.

    Synopsis: Ohio's governor attempts to introduce bidding for AE services.

22. (Author not identified). How to engage a design professional. Kansas City Consulting Engineers (no date). Topeka.

    Synopsis: A double-folded brochure describing a step by step procedure, in layman terms, how to go about the QBS selection process for design professional services.

23. (Author not specified). A taxpayer 's look at a sacred cow: public sector design in Massachusetts two decades after the Ward commission. Massachusetts Taxpayer's Foundation Nov 1995 Boston.

    Synopsis: A pamphlet makes a case against bidding of AE services, by anecdotal example and argument.

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    Synopsis: A text on preparing and executing statistical surveys.

25. Bachner, ML. Montgomery county to use fee-based procurement. Consulting Engineers Council of Metropolitan Washington, Nov 1994.

    Synopsis: Reprint of article opposing decision by Montgomery County, Maryland to procure design services based on fee.

26. Borcherding. 1997. Advance legal concepts. University of Texas at Austin. Unpublished.

    Synopsis: Class lecture notes and handouts for graduate level course in the legal consequences of changes and delays to construction contracts.

27. Bory LD. 1991. Washington watch - Brook's law still imperiled by federal agencies. (?). American Consulting Engineer.

    Synopsis: Government agencies varying Interpretation of the Brook’s bill challenged.

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    Synopsis: Reprint of an article celebrating the spread of the QBS assistance program innovated by the Wisconsin AIA chapter.

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    Synopsis: A text on making causal inference in statistical analysis.

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    Synopsis: The Comptroller General reaffirms, upholding the Federal Highway Administration's (FHWA) election not to follow QBS procedures for procurement of research work, noting that, although the work could be performed by a professional engineering firm, the work could also be performed by other types of firms.

31. Decisions of the Comptroller General. Contracts-small business concerns-awards; matter of Richard Sanchez associates [B-218404.2, B-218474] pages 603-605

    Synopsis: The Comptroller General upholds the Corps of Engineers rejection of a small business firm as best qualified firm under the Brook’s Act, over the Small Business Administration's certificate of competency.

32. DeFraites AA. 1989. Fee versus quality. Journal of Professional Issues in Engineering Vol 115 No 2 pages 125-128.

    Synopsis: The author, speaking as the chairman of Council on Federal Procurement of AE Services, discusses issues relating design service selection methods to project success.

33. Ennis RS. A checklist for writing effective requests for proposals. Des Moines. Geotechnical Services, Inc. Circa May 1994.

Synopsis: A short pamphlet aimed at small entities unfamiliar with the writing of a Request-for-Proposal (RFP) for AE services.

34. Federal acquisition regulation: FAR part 6 - competition requirements. US Government Printing Office.

Synopsis: Federal procurement regulations concerning full and open competition.

35. Federal acquisition regulations: FAR 36.6 - architectural-engineering services. US Government Printing Office.

Synopsis: Federal implementation of the Brook's Act requiring QBS procedures for AE services on federal projects.

36. Fisher, I, 1933, Inflation?, Adelphi, NY

37. FW Dodge Co. Current construction projects database (commercial electronic database, accessible by subscription only). Accessed 30 Jul 96.

Synopsis: An electronic database of pending construction projects, searchable with filters for time, type, and value.

38. Gibson, GE. 1997. Capital facility finance. University of Texas at Austin. Unpublished.

Synopsis: Class lecture notes, handouts, papers, research, and discussions for graduate level course on capital facility finance aspects of construction projects methodologies and procedures.

39. Glenn, ND. 1998. Survey research methods. University of Texas at Austin. Unpublished.

Synopsis: Class lecture notes and handouts and discussions for graduate level course on survey research methods and problems.

40. Graziano A, Raulin M. 1996. Research methods - a process of inquiry. 3rd Ed. NY. Longman.

Synopsis: A text on research techniques and statistical analysis.

41. Grogan T. International: US lowest in design fees. ENR 27 Mar 95 pages 34 - 78.

Synopsis: An international comparison of design fees.

42. Hampton D. 1994. Procurement issues. Journal of Management in Engineering Vol.10 No.6 pages 45-49.

Synopsis: A discussion of the advantages and disadvantages inherent in procuring AE services by bidding, qualifications, and a two-step process.

43. Hatheway AW. Forum: end the evils of bid competition. Civil Engineering Nov 95 page 6.

Synopsis: The author describes the symptoms that the "disease" of bidding on professional services has caused since the US Justice Department ordered the American Society of Civil Engineers to remove an ethics clause banning bidding for professional services.

44. Ichniowski T, Winston S, Angelo WE. Washington observer: Brooks act may cover defense. ENR 7 Nov 95 page 5.

Synopsis: US Congress considers broadening the Brook's act coverage.

45. Kalton, G. 1983. Introduction to survey sampling. Newbury Park. Sage Publ.

Synopsis: A text on preparing and executing statistical surveys.

46. Knoke D, Hohrnstedt GW. 1982. Statistics for social data analysis. 3rd Ed. Itaska (IL). F.E. Peacock.

Synopsis: A text on statistical analysis techniques.

47. Korman R, Kohn D. Cover story: when price is paramount. ENR 3 Jul 95 pages 24-26.

Synopsis: Price competition among design firms is a growing trend.

48. Lewin JL, Lorenze BA. The Brook's architect-engineer act: promoting quality in federal procurement. National Contract Management Association. 1994 Dec Vol. 5 No. 12,

Synopsis: A very complete history of the Brook's bill that mandated QBS procedures for federal agencies. The article also provides the history that pre-dates the Brook's bill, and subsequent legislative activity that attempted to eliminate the 6% fee limit.

49. Lewis S. Knowledge, expertise, experience: the ABC's of QBS. Wisconsin Professional Engineer. May/Jun 1992.

Synopsis: An article extolling the virtues of QBS and the QBS Assistance program.

50. Lunch MF. Legal trends: legislation seeks two-phase design-build for federal agencies. Building Design & Construction. Sep 94 page 41.

Synopsis: QBS-like procedures promoted for design-build projects for federal agencies.

51. Lunch, MF. Legal trends: public design/build nixed in Texas, Florida. Building Design & Construction. Jun 91 page 45.

Synopsis: Public design-build projects ruled not legal because professional design services are procured by low bid, contrary to state professional services procurement acts.

52. Means building construction cost data. 1996. RS Mean Co., Kingston, Mass.

Synopsis: Unit costs estimates are provided for building systems, components, materials, labor and equipment, plus adjustment factors for location, region, and size. Tables are also provided for converting costs from one base year to another and forecasting price changes.

53. [M.R. Mikkilineni v. United Engineers & Constructors, inc.] 485 Federal Supplement 1292, pages 1292-1299.

Synopsis: The propensity of the Brook's Act to favor selection of large, established firms was challenged as discriminatory against minorities and individuals. The court did not dispute that contention, but the case was determined on other grounds.

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55. National Society of Professional Engineers (NSPE). Internet web site. http:\\www.nspe.org. Accessed 30 Jan 2000.

56. Paarlburg D, 1993, An analysis and history of inflation, Praeger Publishers, CT.

Synopsis: A historical compilation of fifteen inflationary periods from ancient Rome to the recent US economy from 1993 and on. Also included is a compilation of price changes for 30 countries.

57. PMI. 1996. A guide to the project management body of knowledge. 182 p. Electronic version via the Internet. http:\\www.pmi.org. Accessed 12 Feb 2000.

Synopsis: A general treatise of project management areas of knowledge applicable to many industries.

58. PSMJ 1996 design services fee survey. PSMJ Resources Inc. Practice Management Associates Ltd. Newton, Massachusetts.

Synopsis: A Professional Services Management Journal sponsored publication issued annually, consisting of a 200+ page report of an annual survey of AIA design firms. The survey includes assessments of competition and price pressures on design firms.

59. Qualifications-based selection – state by state. (publisher and date of publication unknown)

Synopsis: A one-page checklist of all state AE selection laws, including 31 states with QBS laws. Includes Maryland as a QBS state, which makes the list appear to be current.

60. Reina P, Tulacz G. The top 200 international design firms. ENR 24 Jul 95 pages 34-53.

Synopsis: A source listing of international design firms.

61. Schmuckler N, Marcus E (editors), 1983, Inflation through the ages: economic, social, psychological, and historical aspects, Brooklyn College Press, NY.

    Synopsis: A compendium of 53 different articles by 56 different authors around the world detailing different aspects of inflation.

62. Schriener J. Design: high overhead lowers cost. ENR 3 Jul 95 page 14.

    Synopsis: Automation costs in overhead rates a hard sell to cost-conscience customers.

63. Society of American Military Engineers (SAME). Internet web site. http:\\www.same.org. Accessed 10 April 2000.

64. Society of Women Engineers (SWE). Internet web site. http:\\www.swe.org. Accessed 2 Feb 2000.

65. Speigel, M. 1975. Theory and problems of probability and statistics. Schaums Outline Series, McGraw Hill, NY.

66. Sudman S, Bradburn NN. 1982. Asking questions - a practical guide to questionnaire design. San Francisco. Jossey-Bass Publ.

    Synopsis: A text on formulating and validating questions to be used in survey research.

67. Tulacz G. The top 600 specialty contractors. ENR 20 Nov 95 24 page supplement.

    Synopsis: A source listing of specialty construction contractors by name and sector.

68. Tulacz G, Schriener J. Going global: the top international contractors. ENR 28 Aug 95 pages 83-102.

    Synopsis: A source listing of international construction contractors by name and sector.

69. Tulacz G. Competition, government cost cuts worry designers/The Top 500 Design Firms. ENR 3 Apr95 pages 34-78.

    Synopsis: A source listing of domestic design firms by name and sector

70. Vanden-Bosch J, Mouer SR, Gibson GE, O'Connor JT. 1996. Plan for research into architectural/engineering services selection method: phase I final report. University of Texas at Austin. Construction Industry Institute.

    Synopsis: Report on a research into the relation of design service provider selection (QBS vs. Non QBS) and project success.

71. University of Michigan. Internet digitized dissertation library. http:\\wwwlib.umi.com. Last accessed 27 May 2000.

72. USC, Selection of architects and engineers. USCA 40 Subchapter VI, §541 through §544 (pages 184-187).

Synopsis: Codification of the Brook's act.

73. Wright G. Maryland ends price-based selection. Building Design and Construction. 1985 Aug.

Synopsis: Announcement that Maryland's Legislature has removed price considerations from AE selections over $100 thousand.

APPENDICES

APPENDIX A

Evaluation of Florida vs. Maryland

EVALUATION OF FLORIDA vs. MARYLAND

(References keyed to Annotated Bibliography)

A review of AIA publication titled:

Selecting Architects and Engineers for Public Building Projects: An Analysis and Comparison of the Maryland and Florida Systems [1]

AIA FINDINGS

General. The AIA publication reviewed herein is a 95-page paper comparing the AE selection processes of Maryland and Florida between 1975 and 1983. Florida used a qualifications-based selection (QBS) process, and Maryland used a "best value" selection process weighing both qualifications and price. The AIA paper states that both state's user agencies were pleased with their respective systems and that the Maryland agencies did not agree with the report's conclusion that the Florida's QBS system was superior to Maryland's "best-value" selection system.

This AIA document is important to address because it was used to influence legislation to change Maryland to a QBS form of AE selection [73]. The AIA report aggregates the AE and construction costs over a nine-year period, from 1975 to 1983, for Maryland, and over a similar period for Florida. In addition, a separate four-year period from 1980 to 1983 was evaluated for the Florida University construction program.

AIA Findings. The AIA comparison parameter is *AE selection cost*, calculated according to *Equation 1*, below.

Equation 1) *AE selection cost = AE Fee + Administrative costs + Preparation of Programs + Delay*

The results from *Equation 1* are tabularized and *AE selection cost as a percent of construction* is calculated. The report results are presented in Table 1, below.

Table 1: AE Selection Costs			
ITEM	**Maryland (GSA)**	**Florida(GSA)**	**Florida (Univ.)**
AE Fee	$ 22,365,000	$ 55,336,000	$ 13,696,000
+ Administrative costs	$ 3,212,000	$ 3,216,000	$ 269,000
+ Preparation of Programs	$ 776,000	$ 0	$ 0
= Subtotal	$ 26,353,000	$ 58,552,000	$ 13,965,000
+ Delay	$ 41,026,000	$ 0	$ 0
= AE Selection Costs	$ 67,379,000	$ 58,552,000	$ 13,965,000
Total Construction Costs	$518,000,000	$875,000,000	$191,09,3000
AE Selection Costs (percent of total construction)	*13.0%*	*6.7%*	*7.3%*

Based on *AE selection costs as a percent of construction*, the report concludes that Florida's AE selection cost as 6.7% to 7.3% of construction is superior to Maryland's 13%, imputing that QBS yields superior results to non-QBS AE selection procedures. However, if the *delay* cost imputed by the AIA report is ignored (for the moment), then the outcome would be reversed, as presented in Table 2, below.

Table 2: AE Selection Costs (sans delay)			
ITEM	**Maryland (GSA)**	**Florida(GSA)**	**Florida (Univ.)**
= AE Selection Costs (sans delay)	$ 26,353,000	$ 58,552,000	$ 13,965,000
Total Construction Costs	$518,000,000	$875,000,000	$191,09,3000
AE Selection Costs (sans delay) (percent of total construction)	*5.1%*	*6.7%*	*7.3%*

For the case presented in Table 2, Maryland's 5.1% is better than Florida's 6.7% to 7.3%. Since so much rides on the imputed *delay* cost for Maryland, it may be instructive to evaluate how *delay* is imputed in the report.

DELAY COST

Imputing Delay. The AIA report imputes a design *delay* time by finding that Maryland completed design of a construction contract an average of 9.9 months later than Florida, measured from the point in time that budgets were approved to the time that design is complete. The project performance times of various phases of Maryland and Florida determined in the report are presented in Table 3, below.

Table 3: Average Execution Time (months)

Project Phase	MARYLAND(GSA)	FLORIDA(GSA)	DELAY
Planning (budget submittal to approval)	11	9	(not counted)
Program Development	6	4	2
AE Selection process	5	2	3
Design	20	16	4
Construction	18	14	(not counted)
TOTAL	60	45	9

The 9 months of total design delay from the above table is more precisely adjusted to a value of 9.9 months on page 20 of the report.

Imputing delay cost. The 9.9 months of delay in the design process from above is input to Equation 2) below to arrive at a delay cost as follows.

Equation 2) Delay cost = (average delay time) x (average rate of inflation) x (construction costs)
= (9.9 months) x (0.8% inflation/month) x ($518, million)
= $41,026,000

It should be noted that the imputed delay cost of $41,026,000 is one-and-a-half times larger than the $26,353000 aggregated actual design cost reported for Maryland.

EVALUATION

Accepting the data presented in the report, and the determination of performance times at face value, five questions remain to be evaluated:

1) Is 9.9 months of "*delay*" in a four to five year government project cycle meaningful?
2) Is the aggregation of project costs in historic dollars appropriate?
3) Is the *delay* cost appropriately calculated?
4) Is the *delay* cost, if appropriate, a legitimate *design* cost?
5) Are the report's findings statistically valid?

Meaningful delay. In order for *delay* to be meaningful, comparable projects in Maryland and Florida should be compared. For example, a hospital is much more elaborate to design and build than an office building, and would be expected to take considerable more time in the design and in the construction. Insufficient data is presented in the report to properly assess whether comparable projects are compared between Maryland and Florida.

Aggregation of project costs. To properly aggregate the price of construction or design over a period of years with high inflation, the effects of inflation must be removed by restating the value of each contract in the same base year, e.g., 1990 dollars [52, 56, 61]. The report sums contract prices of 174 construction contracts issued over nine years (1975 to

1983) in *historic* dollar amounts, and does not convert the project costs to a common year base. Estimating manuals such as RS Means [51] offer tables and charts to facilitate such conversion. For example, assume Project A and Project B are each estimated to cost $1 million if initiated in 1 Jan 1985. If Project A were to begin on time, and project B were to be delayed one year, the price of project B would eventually be restated in terms of deflated 1986 dollars. Project A would cost $\$_{85}1$ million and Project B would cost $\$_{86}1.05$ million, assuming a constant 5% inflation rate. But both project A and project B would still cost $\$_{85}1$ million in 1985 dollars.

Delay costs appropriately calculated. There are three cases where delay in the design process might occur and cause a real project cost impact. The impact of delay is different for each case. A fourth case is discussed, which is the inflation delay claimed in the report. These four cases are presented in Table 4, below.

Table 4: Delay Cost Cases

Case	Description	Operator	Impact
1	Commercial projects	Time value of money	Profit stream
2	Government projects	Cost-Benefit ratio	Benefit
3	Awarded construction contracts	Completion delay	Construction cost
4	Design delay cost	Inflation	(questionable)

Commercial projects. A delay in completing design might have an adverse economic effect on a *commercial* project, where the *time-value-of-money* is a consideration in calculating potential *profit* streams. In fact, the decision to implement a commercial project is usually based on whether sufficient after-tax profits would be generated in a reasonable time [38]. The measure is usually whether the calculated rate of return on investment capital meets or exceeds a predetermined value[38]. In time periods where inflation is a significant factor, the *real* rate of return would be of interest, which can be determined from the Fisher[36] equation (Equation 3, below).

Equation 3) $(1+i) = (1+r) \times (1+\rho)$, *where* r = *real rate of interest,*
ρ = *rate of inflation, and*
i = *nominal or contract rate of interest.*

The entire process for a commercial project may be measured in weeks. None of the projects in the report were commercial projects, and the report did not claim or address any *time-value-of-money* concerns.

Government projects. Government projects generally are not based on commercial economic considerations. Government projects are most often justified economically using a *cost-benefit ratio* approach, where dollar values are assumed for intangible and tangible social benefits assumed over the estimated useful life of the project. The value of assumed social benefits is often dependent on the density of human populations to be served by the project. The process of identifying and planning potential worthwhile public projects is rather long, often measured in years. Separate annual budget cycles often occur for planning, design, and construction. Many government projects are initiated in the planning phase because of political considerations, then may remain in the planning cycle for years until a benefit-cost ratio of 1.0 or greater is achieved, usually due to an increase in population density in the project area of consideration. Proposed projects that eventually attain a benefit-cost ratio of one or greater are then eligible for inclusion in the next annual budget cycle for design. The decision to include a project in the budget for design and/or construction may also depend on the availability of public funds, which can result in otherwise worthwhile projects being deferred. Cost-benefit analysis generally does not factor in the effects of inflation. No *cost-benefit* impact is claimed or addressed in the report.

Awarded construction contracts. Delay impact on awarded construction contracts may occur due to a delay in the design process, especially on fast-track projects, where design and construction overlap. Such delay costs occur because the construction contractor may have to stop work because of the lack of sufficient design, resulting in idle labor or equipment standing by, and/or extended overheads. Delay costs due to inflation may even occur if the delay is long enough, and the contractor had not adequately planned for it. Generally, however, construction contractors are expected to factor inflation into their original bids, and are not separately compensated for delay costs attributable to inflation, except in rare cases on multiple-year contracts with inflation-adjustment clauses. The report did not address or claim any delay impact attributable to construction delay of an awarded contract.

Inflation as a cost factor. The report assumes that if the average construction contract for Maryland would have been awarded 9.9 months earlier it would have been priced lower by the amount of inflation. There is no argument with this assumption. In fact, it is common to adjust a project cost estimate for the effects of inflation when a significant time lapse occurs between the creation of the cost estimate and the award date of a contract. However, such inflationary price growth is merely a reflection of the falling purchasing power of currency, and not a real project cost growth for the following reasons:

1) Inflation is purely a monetary phenomenon [36, 56, 61]. That is, currency does not hold a constant value over time--its value changes over time due to inflation. A dollar spent in 1980 is not the same value as a dollar spent in 1981. Thus contracts awarded in one year are not directly comparable to contracts awarded in another year. The buying power of the dollar decreases at the rate of inflation, but in true inflation, the buyer's dollar income eventually adjusts upward to compensate. Specifically, it can be argued that the tax revenues of the state will increase because of inflation [56, 61].

2) To properly compare or aggregate the value of contracts issued in different time periods, the contract amounts should be stated in the same base year, e.g., 1980 dollars. When this is done, the effect of inflation on currency is removed, and the contract amounts are directly comparable and can be meaningfully aggregated.

3) As commodity prices rise due to inflation, individual, corporate and government incomes and revenues also rise to compensate, although temporary disparities occur. The negative side of inflation is that currency owners suffer permanent losses due to depreciated value of the currency they possess. The positive side of inflation is that borrowers enjoy permanent gains by the reduced value of their loan balances and monthly payments. Government at the federal, state and local levels tend to be net borrowers, and thus net beneficiaries of inflation. Government revenues tend to rise because their tax structures are largely based on percentage rates (e.g., sales taxes, income taxes, etc.) [36, 56, 61]

Delay as a design cost. Even if the delay cost due to inflation were accepted as legitimate, it would be a *construction* cost growth, not a *design* cost growth. There would be no justification for including such costs as part of the design process. In fact, the price increase due to inflation for the delay would automatically reflect in higher construction prices, and the design prices would be scarcely affected.

Statistical validity. The report does not address or perform any statistical process ruling out random chance as an alternative explanation of the performance differences between Maryland and Florida. Furthermore, legislative remedies should require that causality be established. No statistical process is performed or presented in the report that would infer causality.

SUMMARY

Earlier in this evaluation, five questions were asked. Below is a summary of the evaluation for each question.

Question 1. Is 9.9 months of "delay" in a four to five year government project cycle meaningful?

Delay in design completion is generally not as meaningful for government projects as it is for commercial projects. An exception could exist for emergency projects, or revenue-producing projects such as publicly-funded sports stadiums and convention centers, but no such exception is claimed in the report. Moreover, comparable project types are required in order to compare design performance times. It can not be determined from the data reported whether project types are comparable.

Question 2. Is the aggregation of project costs in historic dollars over the study period appropriate?

Before costs are aggregated over multiple years, individual components should first be re-stated in a common-year base. The report errs in aggregating historic dollar amounts.

Question 3. Is the delay cost appropriately calculated?

Inflation is not a valid cost factor for calculating "delay" costs. The report errs in assigning a delay cost for inflation.

Question 4. Is the delay cost, if appropriate, a legitimate design cost?

Even if inflation-generated delay costs were accepted as calculated in the report, they would be increased *construction* costs, not increased *design* cost. The report errs by the inclusion of delay as a *design* cost.

Question 5. Are the report's findings statistically valid?

No statistical analysis is performed ruling out random chance as an alternative explanation or establishing a causal inference.

CONCLUSIONS

Imputing a *design* cost for the inflation of *construction* prices caused by perceived delays in awarding construction contracts is improper. Moreover, such inflation effects on construction pricing must be removed in order to properly aggregate construction costs over a nine-year time span of the report study.

When the effect of inflation is removed from the comparison of Maryland and Florida's design process, the result is opposite of the result reported in the study. Maryland’s design cost of 5.1% of construction then compares favorably to Florida's 6.9% (GSA) or 7.3%(Univ.). In fact, with inflation removed, Florida's design cost is 35% to 43% higher than Maryland's. Therefore, the report's findings must be considered inconclusive.

APPENDIX B

SURVEY PARTICIPATION REQUEST

with

SURVEY INSTRUCTIONS

Simon Mouer, PE Phone (512) 291-1057
PO Box 151764, Austin, TX 78715-1764 email: smouer@netzero.net

SUBJECT: Survey on Construction Project Organization and Outcome

Dear Project Owner

I am a doctoral candidate gathering data for research purposes. Your recently completed project (described in the enclosed FW Dodge report) has been randomly selected from a pool of about 1,000 projects in the building, horizontal, and utilities sectors. Data provided from your project will logically extend the FW Dodge database to include actual completion data, which can then be used for future research and study.

The importance of your anonymity and the confidentiality of your data will be respected and preserved. Your raw data submission will be identified only by a code, which is linked to only one copy of the project sheet enclosed. After your data has been proofed for error or omission, the coded project sheet will be destroyed so that linkage of your firm to the raw data is not possible. Furthermore, all raw data on dollar amounts will be reduced to percentages or ratios so that specific project identification is not possible.

The attached survey instrument has been designed and formatted to facilitate your data entry. The data requested is on project organization and outcome, specifically, how the project was contracted, what the contract award criteria was, and what the outcome was in terms of cost and time growth. In addition, specific information is requested for each construction contract modification, including the root cause of the modification. More detailed instructions for filling out the survey form are given in the Survey Instructions printed on the reverse side of the sheet containing the FW Dodge data for your project.

Would you as owner, or your project manager, or the person most familiar with the project, be so kind as to complete the survey form enclosed for this project? If the contact information in the FW Dodge report is out of date or has changed, please furnish me with updated contact information, or pass this on to the appropriate party. I thank you for participating in this research. For further information or explanation, please contact the undersigned.

Sincerely,

Simon Mouer, PE
Doctoral Candidate

Encl.: 1. FW Dodge report
2. Survey Instructions (on the back of the FW Dodge Report)
2. Survey Form
3. Self-addressed, postage-paid, return envelope

SURVEY INSTRUCTIONS

This survey contains four parts. The format is designed to minimize the data you enter, and allow you to visually relate row-wise project organization data entered in Part 1 with the corresponding contract attributes presented in the columns in Parts 2 & 3. Parts 1, 2, and 3 are printed on a one side of single sheet of 8-$^1/_2$ by 11 paper. Part 4 is printed on the reverse side. While the spreadsheet has a lot of information pre-printed on it, the amount of data you actually enter is minimal.

Part 1 records how your project was organized and executed in *prime* contracts. In some cases the owner will have performed part or all of the phase, in which case a column is provided to indicate the percent that was performed by the owner. Typical phases are pre-printed in blue for your convenience. Your project may not use all these pre-printed phases. Please complete Part 1 before moving to Parts 2 & 3.

Part 2 records the owner's criteria for selecting and awarding each prime contract listed in Part 1. Simply place an 'X' in the appropriate columns, and also indicate the weight (expressed as a percentage) that price or qualifications determined award (% price weight + % qualifications weight = 100%.) .

Part 3 records original (at award) and actual (at completion) contract price and contract duration for each prime contract listed in Part 1. Simply input the contract price and duration (in calendar days) at contract award, and the actual contract cost and duration (in calendar days) at contract completion.

Part 4 records essential data for each modification made on a construction contract listed in Part 1. Input the following data for each construction contract modification:

1) Construction contract being modified (e.g., CC1, CC2, ...)
2) Modification identifier (e.g., P001, P002, …)
3) Modification price adjustment in dollars ('+' for cost increase, '-' for cost decrease).
4) Modification time adjustment in calendar days ('+' for cost increase, '-' for cost decrease).
5) Root cause of the modification. For a single root cause, simply input an 'x' in the appropriate column. For multiple root causes indicate the percentage contribution in each appropriate column. For projects with very numerous modifications, you may submit your project modification summary sheet, but add a column indicating root cause. You may identify the root cause by using the column header numbers 1 through 11 on the survey form.

If you would like to comment on the form, format or content of this survey, please use the optional Survey Evaluation form below, after you have completed the survey.

Pleas put your completed survey form in the pre-addressed, stamped envelope provided. Include the Survey Evaluation below with your comments, if you choose to complete it, or if you have comments.

SURVEY EVALUATION (OPTIONAL)

Place an 'X' on the scale to the right in the location that most appropriately represents your feelings on the questions.

		Strongly Disagree									Strongly Agree		
Example	*I like taking surveys.*	1	2	3	4	5	X6	7	8	9	10		
1	I like the spreadsheet format of this survey.	1	2	3	4	5	6	7	8	9	10		
2	The survey was implicitly easy to follow.	1	2	3	4	5	6	7	8	9	10		
3	The detail of this survey was about right.	1	2	3	4	5	6	7	8	9	10		
4	The time to complete this survey was acceptable.	1	2	3	4	5	6	7	8	9	10		
5	Indicate the time to complete this survey. minutes	5	10	15	20	25	30	35	40	45	50	55	60

COMMENTS: If you have any comments on this survey, the format, or anything else, please share them with us:

APPENDIX C

SURVEY INSTRUMENT

SURVEY FORM

ID Code

PART 1: PROJECT ORGANIZATION

Please complete Part 1 before starting Part 2 or Part 3

PART 2: CONTRACT AWARD CRITERIA

For each prime contract, select the one best statement in each process that best describes the award criteria used. (Put an "X" in the appropriate column).

PART 3: CONTRACT COST AND DURATION

For each prime contract insert the original contract cost and duration, and the final cost and actual duration at contract completion

Prime Contracts List the **prime** contracts used to execute your project for each applicable Project Phase indicated. For phases wholly or partially performed by the owner, list the % owner performed in the column to the right. (List only prime contracts, not subcontracts) It is not necessary to name a company, just the company function (e.g., Design AE)	**% of phase performed by owner**	Qualifications (Pick one only): No separate process	Qualifications: Evaluate separate from price	Qualifications: Evaluate with Price	Qualifications: Other (specify)	***Award weight: (%)*** *Indicate what weight (%) the contractor's QUALIFICATIONS played in deciding to award to him (% qualifications + % price = 100%)*	Price Determination (Pick one only): Negotiated before selection	Price Determination: Negotiated after selection	Price Determination: Competitive Bid	Price Determination: Other (specify)	***Award weight: (%)*** *Indicate what weight (%) the contractor's PRICE played in deciding to award to him (% qualifications + % price = 100%)*	COST: **Original Contract Amount** at award ($)	COST: **Final Contract Amount** after completion ($)	TIME: **Original Contract Duration** at award (calendar days)	TIME: **Final Contract Duration** after completion (calendar days)
Example: XYZ Consultants	*0%*		*X*			*75%*		*X*			*25%*	*$ 50,000*	*$ 75,000*	*540*	*620*
Project Management															
Planning															
Geotech															
Design															
Long Lead Equipment.															
Construction Management															
Construction															
Furniture, Fixtures, & Equipment															
Start-up (Plants only)															
Other (specify)															

Comments/Notes

Project cost totals

Turn page over to complete survey

PART 4: PRIME CONSTRUCTION CONTRACT MODIFICATIONS

For each prime construction contract modification, indicate cost and time impact on contract completion. Indicate the root cause of the modification.
For mutiple causes indicate % contribution of each cause. For numerous modifications duplicate this page as necessary.
Alternatively, submit project data sheet of construction contract modifications, annotated with Root Cause number, or percentage if mutiple causes.

Contract Modifiction				Root Cause of Contract Modification										
				1	2	3	4	5	6	7	8	9	10	11
					Within Owner's Control		Mal-performance or Interference by Another Prime Contractor (identify below, and indicate % if multiple causes)							
Identify Prime contract Modified	Description of Modification	Modification Price Adjustment + increase - decrease $	Modification Time Adjustment + increase - decrease (cal. days)	**Beyond Owner''s Control**: Acts of God, Force majure, Severe weather, strikes, Civil unrest, etc.	**Owner Retained Risk**: Change in scope, Differing site conditions, etc..	**Owner Failed To Perform** Failure to provide Site Access, etc..	**Project Management Firm.** Poor pre-project planning, poor contracting strategy, poor contract documents, etc.	**Geo-Tech Firm** Error in sub-surface reporting or soil proprties, etc.	**Design Firm** Error in Engineering, Design, Plans, or Specifications, etc.	**Long-Lead Equip. Supplier** Late delivery, etc..	**Construction Management Firm** Failure to coordinate multiple primes, etc.	**Another Construction Contractor** Failure to perform, Late Completion, Liquidated Damages, etc.	**Furniture, Fixtures & Equipment Supplier.** Late delivery, etc.	**Other Contracted Party** (specify)
Example	*F005 Addl ar condtioning*	*$2,500,00*	*90*		*75%*				*25%*					
C														
o														
n														
s														
t														
r														
u														
c														
t														
i														
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n														