ANALYSIS OF THE TEXAS A&M UNIVERSITY SYSTEM'S CONSTRUCTION PROJECT DELIVERY METHOD PERFORMANCE: CMAR AND CSP

A Thesis

by

ANDREW EDWARD NEIDERT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2012

Major Subject: Construction Management

Analysis of the Texas A&M University System's Construction Project Delivery Method

Performance: CMAR and CSP

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Approved by:

Chair of Committee,	Leslie Feigenbaum
Committee Members,	James Smith
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ABSTRACT

Analysis of the Texas A&M University System's Construction Project Delivery Method Performance: CMAR and CSP. (August 2012)

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Chair of Advisory Committee: Dean Leslie Feigenbaum

In recent decades, the use of construction manager-at-risk (CMAR) has surged as an innovative construction project delivery method in comparison to traditional competitive bid procurement methods. The conceptual pros and cons of the method are widely accepted throughout the construction industry; however, very little quantitative research exists validating such beliefs. The study presented in this technical paper empirically compares the performance of CMAR to that of the more traditional method of competitive sealed proposal (CSP) in the construction of higher educational facilities. In a study of 33 projects constructed by The Texas A&M University System, 19 procured using CMAR and 14 procured using CSP, observed results show a reduction in schedule growth and change order quantity when using CMAR over CSP. However, additional results show that CSP is more apt to result in decreased project and construction costs than CMAR. Business practices of The Texas A&M University System, statistical significance testing of research data, and practical applications of research findings are included.

ACKNOWLEDGMENTS

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NOMENCLATURE

AACC	Amount Available for Construction Contract
A/E	Architect / Engineer
AGC	Associated General Contractors of America
AIA	American Institute of Architects
BOR	Board of Regents
CMAR	Construction Manager-at-Risk
CO	Change Order
CSP	Competitive Sealed Proposal
DB	Design-Build
DBB	Design-Bid-Build
GMP	Guaranteed Maximum Price
NTP	Notice to Proceed
RFI	Request for Information
RFQ	Request for Qualifications
RFP	Request for Proposal
TCC	Total Cost of Construction
TPC	Total Project Cost

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INTRODUCTION

During the 20th century, the United States of America constructed its built environment using a “low bid” philosophy. Contracts for construction were traditionally procured using simplistic linear project delivery methods, such as design-bid-build (DBB) (see Figure 1). DBB served as the preferred project delivery method dominating the public and private construction industry since contracting reform in 1893 formally separated the design and construction phases, negating the master builder approach (U.S. Department of Transportation – Federal Highway Administration, 2012). In 2009, Senator PatriciaWiggins, author of a number of land development and construction statutes, stated that DBB came about due to “the political favoritism, corruption, and waste associated with major infrastructure projects in the 19th century” (Wiggins, 2009, p.2). DBB was the project delivery method of choice for such a prolonged period of time that it is now commonly referred to as the benchmark, or traditional system. Nearly a century later, modern private and public sectors have sought to diversify their portfolios of available delivery methods in light of the constructability, budgetary, communicative, and productive disadvantages of the traditional system (Wilson, 1999). In part, due to the shortcomings of DBB, the United States has experienced a growing interest within the public and private markets to invest in, and experiment with, alternative construction project delivery methods.

Supporters of dynamic methods of project delivery, which overlap design and construction (see Figure 2), propose that the expected benefits of such methods include improved cost and schedule calculation, increased quality of construction, reduced litigation, improved design coordination, and improved stakeholder communication (Rojas & Kell,

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This thesis follows the style of *International Journal of Construction Education and Research*.

2008). However, little quantitative research exists to support such claims. Some research, such as the project delivery systems study of construction manager-at-risk (CMAR), design-build (DB), and DBB published by the (Construction Industry Institute, 1997) present information suggesting measurable benefits of alternate delivery methods. On the other hand, research, such as the evaluation of public contracting in Oregon published by (Williams, 2003), exists suggesting that alternative project delivery methods provide little to no benefit over traditional methods (Rojas & Kell, 2008).

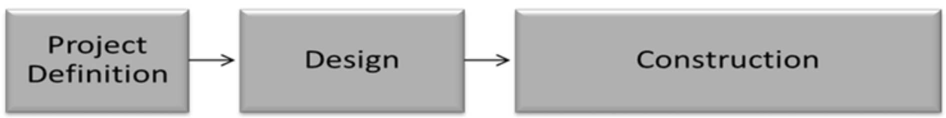

Figure 1. Linear project delivery method process.

CMAR is one of the alternative delivery methods that is rapidly growing in popularity. The growing interest in CMAR throughout the public arena can be identified in the 2005 study conducted by the American Institute of Architects (AIA). The study shows that half of our nation's states, exactly 25 out of 50, have approved legislation incorporating CMAR as an acceptable form of procurement for the construction of public facilities and structures (American Institute of Architects Government Affairs, 2010). However, without quantitative data supporting the use of CMAR, why is it suddenly flourishing in the contracting and construction of our modern day built environment?

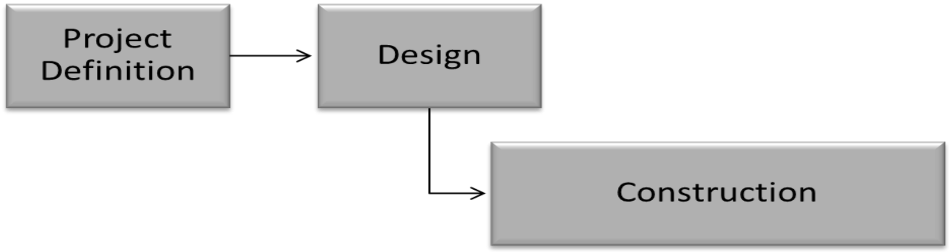

Figure 2. Dynamic project delivery method process.

The study in this paper presents research that empirically compares cost, schedule, and change information for construction projects procured using a more traditional competitive sealed proposal (CSP) method of procurement to that of the dynamic CMAR method. For the purposes of this research, quantitative data has been confined to projects completed by The Texas A&M University System, including 14 CSP projects and 19 CMAR projects valued between $3.5 million and $26 million completed between the years of 2004 and 2011. Results of the study are intended to illustrate the quantitative performance of CMAR when compared to CSP in the arena of higher educational construction.

Definition of Terms

- Amount Available for Construction Contract (AACC): The maximum monetary amount budgeted by the Owner for all Construction Phase services, materials, labor and other work required of the Contractor for completion of a project. The AACC includes, without limitation, the General Conditions Costs, the Cost of the Work, the Construction Phase Fee, and Contractor's Contingency. The Owner may adjust the AACC for changes in the scope of the project before or after acceptance of the Guaranteed Maximum Price Proposal. The AACC does not include Contractor's Pre-Construction Phase Fee. The Final Amount Available for the Construction Contract is the AACC after the Project has been approved by The Texas A&M University System Board of Regents (The Texas A&M University System, 2012).

- AACC Performance Indicator #1: AACC – CMAR GMP or CSP Bid-Amount.
- AACC Performance Indicator #2: AACC – TCC.
- Board of Regents (BOR) Approved Amount: Also known as the Planning Amount; includes the AACC, fees, furnishings, other work, miscellaneous expenses, and contingencies. This represents the entire amount appropriated for completion of a construction project.
- Change Order: A written modification of the Contract between the Owner and Contractor, signed by the Owner, the Contractor and the A/E. A change order may consist of multiple contractual revisions grouped within a single change order (The Texas A&M University System, 2012).
- Change Order Days: Calendar days added to the contractual period between the Date of Commencement (Start Date) identified in the Notice to Proceed with Construction, and the Substantial Completion date identified in the Notice to Proceed (Ramirez, 2012).
- Change Order Quantity: The total number of change orders observed.
- Change Order Ratio: Total change order category volume ($) / Total sample change order volume ($). Change order ratio shows the distribution of a single dollar sent on change between the five change order categories.
- Close-Out Documents: The product brochures, product/equipment maintenance and operations instructions, manuals, and other documents/warranties, as-built record documents, affidavit of payment, release of lien and claim, and as may be further defined, identified, and required by the Contract Documents (The Texas A&M University System, 2012).
- Competitive Sealed Proposal (CSP): Shall be consistent with the definition provided by The Associated General Contractors of America (AGC) as a best value linear delivery method that is designed "to assist public owners in ensuring that evaluation and award of construction contracts using performance factors in addition to cost are conducted in a fair and competitive manner" (Associated General Contractors of America, 2012).

- Construction Documents: Collectively, the Uniform General and Supplementary Conditions; Owner's Special Conditions and Specifications; and the Drawings, Specifications, details, Change Orders and other documents prepared by A/E, its consultants, and by Owner's consultants, that describe the scope and quality of the Project and the materials, supplies, equipment, systems and other elements that are required for construction of the Project that are accepted by Owner (The Texas A&M University System, 2012).
- Construction Manager-at-Risk (CMAR): Shall be consistent with the definition provided by The American Institute of Architects (AIA) and The Associated General Contractors of America (AGC) as the, "The construction entity, after providing preconstruction services during the design phase, to takes on the financial obligation for construction under a specified cost agreement" (Joint Committee of The American Institute of Architects & The Associated General Contractors of America, 2012).
- Contract: The entire agreement between the Owner and the Contractor including all of the Contract Documents (The Texas A&M University System, 2012).
- Contractor: The individual, corporation, company, partnership, firm or other entity contracted to perform the Work, regardless of the type of construction contract used, so that the term as used herein includes a Construction Manager-at-Risk or a Design-Build firm as well as a General or Prime Contractor. The Contract Documents refer to Contractor as if singular in number (The Texas A&M University System, 2012).
- CSP-Bid Amount: The agreed-upon dollar amount stipulated in the contract representing the amount the Owner shall pay the Contractor for performance of CSP services.
- Dynamic Construction Project Delivery Method: The comprehensive process of assigning the contractual responsibilities for designing and constructing a project where the Contractor aids in design prior to the completion of construction documents and the start of construction.

- Facility Planning and Construction (FP&C) Department: The overall managing partner of construction projects for The Texas A&M University System throughout all phases of project development.
- Guaranteed Maximum Price (GMP): The amount proposed by the Contractor and accepted by the Owner as the maximum cost to the Owner for construction of the Project in accordance with this Agreement. The GMP includes Contractor's Construction Phase Fee, the General Conditions Cost, the Cost of the Work, and Contractor's Contingency amount (The Texas A&M University System, 2012).
- Institution of Higher Education: An institution that provides an education following the completion of a school providing a secondary education, such as a high school or secondary school. This institution normally includes undergraduate and postgraduate education, as well as vocational education and training. Colleges, universities, and institutes of technology are the main institutions that provide higher education.
- Linear Delivery Method: The comprehensive process of assigning the contractual responsibilities for designing and constructing a project where the Contractor's initial involvement in the project takes place after the completion of design.
- Owner: The Board of Regents (BOR) of The Texas A&M System or its designated representative, which is The Facilities Planning and Construction Department (FPC) when in the context of the research in this paper; however, when in context of construction in general, Owner shall mean the individual, corporation, organization or entity that finances and or possess the rights to the structure upon completion of construction (The Texas A&M University System, 2012).
- Outlier: A value that is at least 1.5 interquartile ranges below the first quartile (Q1), or at least 1.5 interquartile ranges above the third quartile (Q3) (Stat Trek, 2012).
- Project Delivery Method: The comprehensive process of assigning the contractual responsibilities for designing and constructing a project.
- Planning Amount Performance: BOR approved amount minus the total project cost (TPC). The resulting value displays a project's total cost savings or loss.

- Substantial Completion: The date determined and certified by the Contractor, A/E and Owner when the Work or a designated portion thereof is sufficiently complete, in accordance with the Contract, so as to be operational and fit for the use intended (The Texas A&M University System, 2012).
- Total Cost of Construction (TCC): The dollar amount paid by the Owner for A/E, pre-construction, construction, and FP&C services. This amount reflects the actual expenses incurred for construction and includes fees for services such as commissioning, testing, and inspections (The Texas A&M University System, 2012).
- Total Project Cost (TPC): The dollar amount paid by the Owner for A/E, pre-construction, construction, and FP&C services as well as construction contingency, other construction services, and other service expenses. This amount reflects the actual expenses incurred for the entire project and includes, but is not limited to, furnishings, fixtures, equipment, landscaping, kitchen equipment, and parking expenses.
- User: The physical plant representative and or The Texas A&M University System department or college, which will occupy or use a structure upon completion of construction.
- # CO / Mil ($) of TPC: Quantity of change orders / Million ($) of TPC. This value represents the quantity of change per million dollars of TPC.

PROJECT DELIVERY METHOD ANALYSIS

Numerous methods of assigning contractual responsibilities for designing and constructing a project exist in the United States. The allocation of risk plays a major role in the assignment of these responsibilities; and thus, in the selection of a project delivery method. Texas Legislation defines six different project delivery methods as acceptable for use in the construction of higher educational projects. The research presented in this document defines and compares two of these methods: CSP and CMAR.

Competitive Sealed Proposal

In the linear project delivery method of CSP, (see Figure 3) an Owner selects a Contractor based on a combination of two primary factors: the Contractor's qualifications and the bid amount. For this reason, CSP is often referred to in the public sector as "best value" contracting, where the builder is contracted based on either a lump sum amount or a cost-of-the-work up to a guaranteed maximum price (GMP) amount (Flake, 2012). The Associated General Contractors of America (AGC) defines CSP as a best value delivery method that is designed, "To assist public owners in ensuring that evaluation and award of construction contracts using performance factors in addition to cost are conducted in a fair and competitive manner" (Associated General Contractors of America, 2012, p.1).

Texas Public Education Statute, Chapter 44, Subchapter B, Sec. 44.040 (see Appendix A) defines the conditions an institute of higher education must adhere to in order to execute a CSP contract for construction. Prior to selecting a Contractor, the institute of higher education, also referred to as the Owner in this document, selects an Architect/Engineer (A/E) in accordance with the Brooks Act based on competency and credentials, who then prepares construction documents for the project. The Owner may only negotiate the cost of design after the selection of an A/E firm. Following completion of construction documents, the Owner publically advertises the project to Contractors in a "call for interest," determining which companies desire to bid and perform the work. Interested firms receive a request for proposal (RFP), which includes construction documents, weighted selection criteria, project scope, project budget, schedule constraints, and other pertinent information. Following public receipt and announcement of proposals, the Owner ranks and scores each submission based the following criteria: price, reputation, experience, prior performance, existing relationships, safety record, proposed project personnel, proposed methods of construction, historically underutilized businesses (HUB) projections, other relevant factors (Joint Committee of The Associated General Contractors of America & The Council of Educational Facility Planners International, 2012). At this point, the Owner negotiates in good faith the contract terms and conditions with the highest ranked firm to achieve the "best value" for the proposed construction project. Should the parties not strike an agreement, the Owner may then negotiate with subsequently ranked firms until construction terms and conditions are agreed upon, at which point the Owner executes the contract for construction and provides a notice to proceeded (NTP) in accordance with the terms of the contract.

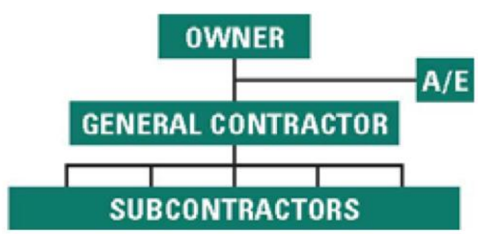

Figure 3. Hierarchical CSP diagram.

Construction Management-at-Risk

The dynamic project delivery method of CMAR (see Figure 4) allows for the alignment of the Owner, A/E, and Contractor in order to facilitate the design and construction process. In 2004, a joint committee comprised of AGC and AIA members defined CMAR as a method of procurement that allows “the construction entity, after providing preconstruction services during the design phase, to take on the financial obligation for construction under a specified cost agreement” (Joint Committee of The American Institute of Architects & The Associated General Contractors of America, 2012, p.6). The joint committee further stated that the specified cost agreement is frequently in the form of a GMP.

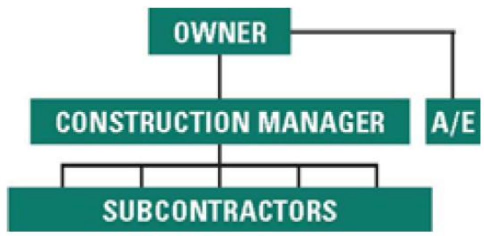

Figure 4. Hierarchical CMAR diagram.

The Texas Public Education Statute, Chapter 44, Subchapter B, Sec. 44.038 (see Appendix B) defines CMAR as, “A sole proprietorship, partnership, corporation, or other legal entity that assumes the risk for construction, rehabilitation, alteration, or repair of a facility at the contracted price as a general contractor and provides consultation to the school district regarding construction during and after the design of the facility” (Texas Legislature, 2012, p.1). By using CMAR in the State of Texas, an institution of higher education selects a Contractor with a “best value” approach, using either a one-step RFP solicitation method or a two-step request for qualifications (RFQ) solicitation. The Owner selects the Contractor either simultaneously with, or at some point after, the selection of the A/E, but before the completion of construction documents (Texas Legislature, 2012); (Appendix B). This allows the Contractor to work with the Designer before the design is complete and before construction begins throughout what is called the pre-construction phase. During this phase, and at a time stipulated by the Owner, the Contractor provides a GMP including the Contractor’s overhead and profit as well as total construction cost (Trauner, 1992). At this point, the Contractor is “at risk” for any construction costs that eclipse the GMP. The Owner may choose to either accept the Contractors’ proposed GMP, or reject the GMP and continue throughout the construction process with a different Contractor. Once the GMP is agreed upon, the Owner awards the Contractor the contract for construction and provides a NTP, with the Contractor taking all of the upside risk. Construction savings may go directly to the Owner, or be split between the parties at a contractually specified rate. Because savings generated throughout construction may be returned to the Owner, it is mandatory that the Contractor “open up the books” to the Owner disclosing all cost information (Rojas & Kell, 2008). Thus, it becomes clear that with CMAR, the Contractor has a stake in the entire construction process, from pre-construction to completion, becoming invested in project success.

Differences between CSP and CMAR

The differences between the CSP project delivery method and the CMAR method are multifold. A side-by-side comparison of the two methods (see Table 1) allows for the identification of each method’s strengths and weaknesses, as well as the display of expected Owner benefits and pitfalls. The clearest difference between the two methods is seen by comparing Figure 1 and Figure 2.

The CSP delivery method is linear in nature, with the Owner’s selection of a Contractor taking place following the full design of a project. Without participation in design, the Contractor is not held liable for items missing in the construction documents, resulting in a reduced contingency fund. Items not shown in the drawings increase the cost incurred by the Owner, providing a potential avenue of profit for the Contractor. Scope added post design due to errors and omissions is charged to the Owner in the form of change orders, which increases the Contractors contract value; thus, covering additional costs incurred. Some Contractors view this as an opportunity to increase their bottom line by charging change-ordered work to the Owner at a marked-up rate. Additionally, a lump-sum contract is often associated with the CSP delivery method where project savings are shifted to the Contractor's bottom line. This may result in the Contractor refocusing interests to find ways to reduce job costs, which can be achieved by decreasing the quantity and quality of materials installed, as well as the methods by which they are installed. For example, a Contractor may be inclined to save money by protecting a finished terrazzo floor during construction with a cheaper polyurethane product rather than with a more expensive Masonite board product. In the event of an accident, such as a hammer falling on the floor, the Masonite will provide better protection than sheet plastic for a surface that once damaged, cannot be returned to its original form. Realistically, the Contractor is not going to replace the entire floor due to one blemish. This may seem negligible; however, "shortcuts" such as these applied to a large project over a long period add up, resulting in an Owner receiving a lower quality product. This may lead to a potential source of friction and concern for an Owner and design team in the construction process.

Table 1. Strengths and weaknesses of CMAR and CSP

	CSP	**CMAR**
Owner holds separate contracts with A/E and Contractor	☑	☑
Contractor selected based on qualifications	☑	☑
Defined project scope prior to construction	☑	
Single point of accountability	☑	☑
Cohesive team driven philosophy		☑
Aggressive bidding	☑	
Ability to fast-track project		☑
Contractor included in design		☑
Change flexibility		☑
Owner privy to all Contractor data via open book policy		☑
Simplicity of project delivery	☑	
Conducive to large or sophisticated projects		☑
Conducive to small or simplistic projects	☑	
Owner retains project savings		☑

Table 1 Continued.

	CSP	CMAR
Increased quality of construction		☑
All work is competitively bid		☑
Lowest construction cost	☑	
Contractor absorbs up-side risk		☑

In contrast to CSP, CMAR is a dynamic project delivery method where the Owner's selection of the Contractor takes place at some point prior to the completion of construction documentation. This allows for a pre-construction phase where the Owner benefits from the Contractor's knowledge and expertise by compensating the Contractor for aiding in design and providing scheduling, value engineering, cost estimating, constructability, and bid packaging advice (Flake, 2012). In addition to pre-construction services, CMAR allows an Owner to "fast-track" a project by beginning construction prior to the completion of design. With the Contractor on board, and often having commenced construction prior to the completion of construction documents, the Contractor has an interest in the accuracy of design. The Contractor can no longer look to the Owner to pick up the cost of items excluded from the drawings. If in good faith, and after providing a GMP, information is missing from the drawings that should have been noticed by a prudent Contractor, however, was overlooked, the Owner passes the cost on to the Contractor, who must have a contingency fund in order to cover the expense. This mutual understanding between the Owner and the Contractor at the forefront of discussions fosters an amicable relationship between the two parties when it comes to the accuracy of design. In essence, due to the Contractor's involvement in design, the Owner is indemnified against design documentation omissions, as well as inflation and escalation (Rojas & Kell, 2008). The Contractor divulges all financial information to the Owner throughout construction. This transparency reduces the incentive for the Contractor to decrease job cost, as the Owner generally retains construction savings. For example, if the Contractor is able to buy out subcontracts at rates lower than expected, possibly due to economic conditions or the Contractor's connections in the subcontracting market, the Owner rather than the Contractor retains cost savings.

Selecting the Appropriate Construction Project Delivery Method

It is widely understood throughout the construction industry that no single project delivery method can best suit the needs of every construction project. However, Owners may wrongfully select a method of procurement based on familiarity or perceived ease of use. In order to choose the delivery method that yields the "best value," the State of Texas requires an Owner to take into consideration the time available to design and construct, budget considerations, and the complexity of the project (Joint Committee of The Associated General Contractors of America & The Council of Educational Facility Planners International, 2012). Supplementing the requirements of Texas Legislation, (Gordon, 1994) suggests that an Owner's ideal construction contracting method should have an optimal mixture of the following four parts:

1. Scope: The portion of the project's tasks – design, construction, and finance – that is assigned to the Contractor.
2. Organization: The business entity with which the Owner holds a construction contract, such as a General Contractor or a Construction Manager.
3. Contract: The agreement of how the Owner will pay the Contractor for work performed, such as a lump-sum or cost-plus payment. These can be divided into two major groups of fixed price and reimbursable contracts.
4. Award: The method used to select the Contractor and/or the price, such as competitive bidding or negotiation.

REVIEW OF LITERATURE

A limited amount of published literature exists comparing specific project delivery methods as they pertain to the construction of higher educational structures. Keeping this in mind, along with the variability of construction, it is not surprising that no significant research exists comparing relatively large homogeneous samples of projects procured using CMAR and CSP within one higher educational system. However, a number of analogous studies have been conducted that lend insight to the research presented within this document.

In 2008, (Rojas & Kell, 2008) conducted a comparative analysis of the cost growth performance of Pacific Northwest Public Schools procured using CMAR and DBB. The objective of their research was to determine CMAR's performance in controlling construction costs when compared to DBB. The researchers made this comparison by analyzing three parameters: change order growth in terms of change order dollars as a percentage of original contract dollars, GMP as a guarantor of total construction cost, bid-buyout data as the difference between the pre-bid Owner's estimate, and the final construction contract cost. A sample size of 297 completed public school projects in various locations throughout the states of Oregon and Washington was used. The following research results define the study's sample: CMAR maintained a 1.55% decrease in change order growth when compared to DBB, only 25% of CMAR projects finished at or below their GMP, and CMAR resulted in a 29% increase in cost growth when compared to DBB. The researchers concluded that a CMAR GMP is not an effective guarantee of the maximum price, and that when compared to DBB, CMAR is not an effective method of cost growth control. However, it should be noted that the studies sample consisted of 273 DBB projects compared to only 24 CMAR projects, suggesting an inaccurate representation of the sample as a whole, and possible statistical insignificance.

Pertaining specifically to change order information, (Riley & Diller & Kerr, 2005) conducted a study of the effects linear and dynamic delivery systems have on the frequency and magnitude of change in mechanical construction. The researchers assembled change order data from 120 new mechanical construction projects procured via the DBB and the DB delivery methods from 1996 through 2002 in central Pennsylvania. After compiling data, the researchers solicited the project manager on each project to identify the source of the 598 known changes in order to group them into two categories: Owner-initiated change and unforeseen conditional change (field generated). Data analysis showed that the average size of all DB change orders in terms of dollars was 50% lower when compared to DBB, and that the average size of unforeseen change order dollars was 86% lower on DB projects. Research results clearly identify dynamic delivery systems as a means of reducing the costs associated with changes in construction. It should be noted that a significant difference in frequency of changes between the delivery methods was not observed. Additionally, the researchers sample consisted of projects constructed by a sole Contractor, suggesting that results cannot be applied to the population of Contractors as a whole.

A similar study conducted by (Hale & Shrestha & Gibson & Migliaccio, 2009), compared DBB and DB by analyzing each method’s performance based on the metrics of time and money. The sample consisted of 77 enlisted living quarters (39 procured using DBB and 38 using DB) constructed by the Naval Facilities Engineering Command. After adjusting for time and location as well as outliers, the authors concluded that DB exhibited a 2% reduction in cost growth per bed, with a time growth in days more than double that of DBB. In addition, (Love, 2002) researched the influence that linear and dynamic project delivery methods have on rework costs using 161 construction projects throughout Australia. Through a questionnaire survey, the researcher concluded there was no significant difference in rework costs based on differing project delivery methods.

Notably pertinent to the CMAR and CSP study presented in this document, (Septelka & Goldblatt, 2012) surveyed 36 government agencies that used CMAR in lieu of competitive bidding over a 13-year span. The researcher's survey measured project performance based on the following eight parameters:

1. Schedule performance,
2. Cost performance,
3. Contract changes,
4. GC/CM selection process,
5. Subcontractor selection process,
6. Use of third party consultants,
7. Project claims and protests filed,
8. Quality performance.

In total, the survey represented 108 Washington State Public Works construction projects procured using CMAR with an aggregate volume of $6.6 billion. The research's survey results showed that 98% of the completed projects met or exceeded quality standards in terms of schedule and cost. By statistically analyzing the 2009 ENR Best Construction Projects in Texas, (Rajan, 2012) showed that CMAR was the predominant project delivery method. The researcher further concluded that CMAR consistently performed better than alternate delivery methods in change order management. Furthermore, it was concluded that projects procured using competitive bidding experienced a considerable decrease in overall project performance. Representing the only discovered research comparing the procurement methods of higher educational facility construction in the State of Texas, (Beville & McDermott & Smith & Peterson, 2010) administered a 3-part survey in 2007 to research project delivery preference at various Texas universities. The researcher's survey was designed to measure the importance of Owner interests, the Owner's preferred project delivery method, and other project-specific information. Survey data collected represented 238 construction projects spread over the campuses of five institutions of higher education with an aggregate dollar volume of $5.15 billion. The author's survey results unveiled data showing that CMAR was the most widely used project delivery method by university systems in the

State of Texas. CMAR received the highest survey rankings by all five institutions in regards to cost, value, and schedule performance, with one university respondent citing that the method allowed for the greatest value per dollar spent of state appropriated funds. Interestingly, survey results showed that CSP was a distant second favorite among the four delivery methods surveyed, which also included DBB and DB.

STATE OF TEXAS LEGISLATION ON PUBLIC EDUCATION CONSTRUCTION

Texas legislation provides public school districts and higher education intuitions with a number of project delivery methods that they may select from at their own discretion, in order to procure and construct a structure. Specifically, Texas legislation delineates the contractual boundaries inherent in construction between the Owner, A/E, Contractor, sub-contractors, and other stakeholders.

Prior to 1995, public school districts and institutions of higher education were required by law to award construction contracts to a responsive and responsible bidder, or one who completely and accurately responded to bid documents and who is financially stable, based on the bottom line and the nature of competition. Additionally, companies awarded construction management contracts were prohibited from self-performing work (Ford & Salazar & White 1997). In 1995, members of the 74th Texas Legislature took it upon themselves to overhaul the Texas Education Code by passing Senate Bill No. 1. Senate Bill No. 1 addressed a plethora of public educational issues ranging from textbooks to enrollment in an effort to decentralize decision-making authority by shifting management controls of schools to the local school districts (Texas Education Agency, 2012). Included in Senate Bill No. 1, Section 44.031 modified the Education Code pertaining to purchasing contracts. Section 44.031 as modified by the 79th Texas Legislator on September 1st, 2005, included the following:

1. *Except as provided by this subchapter, all school district contracts, except contracts for the purchase of produce or vehicle fuel, valued at $25,000 or more in the aggregate for each 12-month period shall be made by the method, of the following methods, that provides the best value for the district,*
    - *Competitive bidding,*
    - *Competitive sealed proposals,*
    - *A request for proposals, for services other than construction services,*
    - *An interlocal contract,*
    - *A design/build contract,*

- *A contract to construct, rehabilitate, alter, or repair facilities that involves using a construction manager,*
- *A job order contract for the minor construction, repair, rehabilitation, or alteration of a facility,*
- *The reverse auction procedure as defined by Section 2155.062(d), Government Code; or,*
- *The formation of a political subdivision corporation under Section 304.001, Local Government Code.*

2. *Except as provided by this subchapter, in determining to whom to award a contract, the district shall consider,*
    - *The purchase price,*
    - *The reputation of the vendor and of the vendor's goods or services,*
    - *The quality of the vendor's goods or services,*
    - *The extent to which the goods or services meet the district's needs,*
    - *The vendor's past relationship with the district,*
    - *The impact on the ability of the district to comply with laws and rules relating to historically underutilized businesses,*
    - *The total long-term cost to the district to acquire the vendor's goods or services; and,*
    - *Any other relevant factor specifically listed in the request for bids or proposals.*
3. *In awarding a contract by competitive sealed bid under this section, a school district that has its central administrative office located in a municipality with a population of less than 250,000 may consider a bidder's principal place of business in the manner provided by Section 271.9051, Local Government Code. This subsection does not apply to the purchase of telecommunications services or information services, as those terms are defined by 47 U.S.C. Section 153.*
4. *The state auditor may audit purchases of goods or services by the district.*
5. *The board of trustees of the district may adopt rules and procedures for the acquisition of goods or services.*
6. *To the extent of any conflict, this subchapter prevails over any other law relating to the purchasing of goods and services except a law relating to contracting with historically underutilized businesses.*
7. *This section does not apply to a contract for professional services rendered, including services of an architect, attorney, or fiscal agent. A school district may, at its option, contract for professional services rendered by a financial consultant or a technology consultant in the manner provided by Section 2254.003, Government Code, in lieu of the methods provided by this section.*
8. *Notice of the time by when and place where the bids or proposals, or the responses to a request for qualifications, will be received and opened shall be published in the county in which the district's central administrative office is located, once a week for at least two weeks before the deadline for receiving bids, proposals, or responses to a request for qualifications. If there is not a newspaper in that county, the advertising shall be published in a newspaper in the county*

> *nearest the county seat of the county in which the district's central administrative office is located. In a two-step procurement process, the time and place where the second-step bids, proposals, or responses will be received are not required to be published separately (Texas Legislature, 2012).*

By departing from the traditional approach, the new contract purchasing legislation directly affected the construction of educational facilities, allowing school districts and institutions of higher education to select from a variety of different delivery methods in order to achieve the "best value" method of procurement. Furthermore, the Texas Legislature outlined the factors that must be taken into consideration in order to achieve "best value." The Texas Legislature further refined Senate Bill No. 1 through the passing of Senate Bills No. 583, No. 669, and No. 914; changing public education construction once again by providing specific procedures for entering into construction management agent, construction management-at-risk, competitive sealed proposal, design-build, competitive bid, and job order contracts (Ford & Salazar & White 1997).

THE TEXAS A&M UNIVERSITY SYSTEM SPECIFIC CONSTRUCTION BUSINESS PRACTICES

The Texas A&M University System, like any sophisticated Owner, modifies the generally accepted construction business practices in order to best suit current needs.

Change Orders

The Texas A&M University System groups change orders into the following five categories: Required by User or Physical Plant, Facilities Planning & Construction Required, Error or Omission, Unforeseen or Changed Conditions, Design Modification. A change order may consist of multiple contractual revisions grouped within a single change order. For example, a contractual change via the acceptance of an alternative, a drawing omission, and time lost due to adverse weather, all realized concurrently, may constitute a single change order. The Texas A&M University System's procedures also allow change orders to be used as a mechanism of reverting funds back to the Owner (Ramirez, 2012). If at the 85% completion milestone, there is a surplus of job costs, contingency, or general conditions costs, the Owner will issue a deductive change order to the Contractor equal to the value of funds to be returned (The Texas A&M University System, 2012). Thus, it is possible for change order accounts to reflect a negative balance at project completion, especially if a project's design changes in a manner decreasing the scope of work (Ramirez, 2012).

Retainage

The Texas A&M University System Uniform General and Supplementary Conditions Article 10.3.2 (see Appendix C) stipulates that retainage is to be withheld by the Owner at a rate of 5% of each progress payment excluding payments made for pre-construction services. Retainage is released as appropriate and may be initially released following the

65% project completion milestone (The Texas A&M University System, 2012). Final retainage payments are held until the A/E has received as-built drawings, all systems pass final testing and inspection, and the Owner has received closeout documentation. The Texas A&M University System prefers final retainage to be refunded within six months of substantial completion; however, the onus is on the Contractor to submit the required deliverables before final retainage payments will be released by the Owner (Ramirez, 2012).

Contingency

The Texas A&M University System strives to apply a five and five rule of contingency to its construction projects procured using CMAR. The Owner carries a contingency equal to 5% of a project's AACC and requires the Contractor to carry the same, resulting in a total project contingency fund equal to 10% of a project's AACC. The Owner controls the Contractor's contingency throughout the project requiring a written proposal from the Contractor to exhaust any contingency funds (Gay, 2010). All remaining monies in the Contractor's contingency fund at project completion are returned to the Owner.

Accounting and Financing

The Board of Regents' (BOR) approved value for any given construction project represents the total amount of funds available for a project from conception to completion. This value has a 10% built-in float before The Texas A&M University System must return to the BOR requesting additional appropriations, which are made in the form of a C-1 proposal. Essentially, The Texas A&M University System may eclipse the BOR approved amount by no more than 10% of its original value without the approval of the BOR (Ramirez, 2012).

Job Costs

If the actual amount of general conditions costs, cost of work, or Contractor's contingency in a CMAR procured project is less than the agreed-upon amount in the GMP, the cost savings are returned to the Owner. More often than not, The Texas A&M University System allows the User to reinvest these savings into the project, rather than returning them to the Owner. At times, the Owner operates under a "use-it-or-lose-it" scenario, where the User is given leeway to construct the best possible facility within the given budget (Ramirez, 2012). Should a GMP or a CSP bid amount be provided to the Owner at a significantly lower dollar value than the AACC, the User may have the ability to add scope or select alternates until the AACC is reached. This philosophy may differ from other organizations, as constructing for the lowest price is not the main goal; instead the goal is to maximize value by getting as close to the AACC as possible. To take it a step further, in some instances the AACC is eclipsed in order for the User to select a preferred Contractor over one who has a cost of construction within the AACC amount (Ramirez, 2012).

To confirm the accuracy of job costs such as change orders proposed by the Contractor, The Texas A&M University System employs a cost analyst. This individual is charged with confirming labor rates, making sure the cost of materials are consistent across all campus locations, reviewing pay applications, and checking for "honest mistakes" made by the Contractor (Ramirez, 2012).

Schedule

The Texas A&M University System uses change order days to add time to the original contract, and thus as a scheduling metric (Ramirez, 2012). Change order days represent additional days added to the contract due to weather delays, construction delays, and changes to design and construction. The additional days represent days added to the contracted amount of working days from the NTP date to the date of substantial completion.

CSP

The Texas A&M University System's Project Manager Rene Ramirez personally views CSP as a "fancier version of Design-Bid-Build" (Ramirez, 2012) with the ability to analyze every bid, rather than just the lowest bid. The Texas A&M University System uses the CSP process to eliminate outliers, with the idea being that the three or four bids that are fairly close have most likely gotten it "right," while the lowest bids have holes in scope, and the highest bids have too much "fluff" built in. The Owner does not prequalify bidders in using the CSP method of project delivery; instead, any Contractor may bid since the method is effective in weeding out unqualified bidders through the process of establishing "best value" (Ramirez, 2012).

CMAR

The Texas A&M University System strives to select the Contractor at the same time as, or within a few weeks of, the selection of the A/E. The Owner has found that this allows for the maximization of the CMAR delivery method, specifically when the Contractor is able to give input in the early stages of preliminary budgeting and constructability (Ramirez, 2012).

RESEARCH PROBLEM

There are many opinions throughout the construction sector as to which delivery method is generally considered the optimal method; however, due to the large degree of variability in, and the nature of construction, no one particular delivery method may ever evolve to the degree of "one size fits all" status in the industry. Inherent in each method are pros and cons based on the project in question. The construction industry has recently observed an increase in the use of CMAR; however, quantitative research studies supporting CMAR's increase in use are limited and often inconclusive. The information presented in this thesis attempts to identify the quantitative benefits of CMAR in terms of CSP within a sample of projects constructed by The Texas A&M University System.

Research Objectives

Although the frequency of CMAR's use as a project delivery method is well documented, few quantitative studies have been conducted to measure the benefits of its use. To address this shortcoming, the objective of this study is to investigate the effectiveness of CMAR as project delivery method in order to aid in the process of developing industry benchmarks for its efficient use in construction. This study examines CMAR in terms of CSP by using the following construction metrics:

- Project schedule modification: calendar days added to the original contract for construction measured in change order days,
- Project change: number of change orders as well as change order dollar volume,
- Owner cost savings: total change in original project budget as well as total change in original construction budget.

Research Hypothesis

The researcher hypothesizes that within the bounds of the study presented in this thesis, that CMAR will show quantitative evidence of advantage over CSP through the metrics of project schedule modification and project change; however, due to the hard-bid nature of CSP, that CSP will outperform CMAR based on the metric of Owner cost savings.

Research Approach

The approach taken throughout this study is from the perspective of the Owner and The Texas A&M University System, as well as the end User. The information provided from the two conjoined perspectives is blended in order to conclude the actual performance of CMAR in comparison to CSP as it relates to the construction of facilities on the various campuses of The Texas A&M University System.

RESEARCH METHODOLOGY

Data Collection

A systematic collection of The Texas A&M University System's project data was performed via generous access to IMPACT; the Owner's web-based project management information system. The Texas A&M University System uses IMPACT to track project information such as requests for information (RFI's), change orders, budgetary data, scope changes, and schedule modifications, as well as other pertinent project data.

For the purpose of this research, the data on IMPACT was reduced to the projects with the following parameters and was then extracted in order to generate the desired comparison:

- Projects procured using the CMAR and CSP project delivery methods,
- Completed projects with dates of substantial completion ranging between the years of 2004 – 2011,
- Projects with AACCs greater than $3.5 million and less than $26 million,
- Projects with complete records on IMPACT.

Aside from the conditions above, all projects were included regardless of the Contractor selected, type of construction, construction delays, changes made to the original design, impeccable timing, or other factors that may vary from one project to the next. Following the application of the stated parameters, the data sample yielded 19 projects procured using CMAR with a combined BOR-approved dollar value of $299.8 million and 14 projects procured using CSP with a combined BOR-approved dollar value of $173.5 million.

After generating two homogeneous sample subsets of data, the performance of each project record was analyzed. The data for each of the project schedule modification, project change, and Owner cost savings metrics were extracted from individual project records and recorded in Excel spreadsheets (see Appendix D):

1. Project schedule modification,
    - Change order days.
2. Project change,
    - Quantity of change orders,
    - Change order dollar volume required by the User or Physical Plant,
    - Change order dollar volume required by Facilities Planning & Construction,
    - Change order dollar volume due to error and omission,
    - Change order dollar volume due to unforeseen and changed conditions,
    - Change order dollar volume due to design modification.
3. Owner cost savings,
    - BOR approved amount,
    - AACC,
    - CSP bid-amount,
    - CMAR GMP,
    - Original project contingency,
    - TCC,
    - TPC.

The acquisition of project schedule modification and Owner cost savings data was straightforward and directly found on IMPACT; however, securing project change data required additional effort. A total of 270 CMAR and 275 CSP change orders were identified. Because change orders represent a conglomerate of project revisions, each project revision had to be referenced. To do so, the researcher recorded the source of each individual revision within each change order in order to achieve an accurate representation of the dollar volume associated with the five Owner provided change order categories listed above. The systematic analysis of the data defined in Appendix D returns aggregate subsets of data (see Table 2 and Table 3).

Table 2. Aggregate sample budget data

	Budget						
	BOR Approved Amount	**AACC**	**CSP Bid-Amount**	**CMAR GMP**	**Owner's Project Contingency**	**TCC**	**TPC**
CSP	$173,534	$136,298	$128,352	N/A	$13,328	$134,536	$164,589
CMAR	$299,850	$231,748	N/A	$229,533	$24,444	$240,517	$288,726

Note: Values shown are in millions

Table 3. Aggregate sample schedule and change order data

	Schedule	Change Order					
	CO Days	**CO Quantity**	**Required by User**	**Required by FP&C**	**Error/ Omission**	**Design Change**	**Total CO $ Volume**
CSP	1219	275	$4,317,685	$6,619,088	$917,455	$1,487,239	$14,726,266
CMAR	1768	270	$8,466,304	$5,107,825	$2,078,306	$2,878,749	$19,491,139

Adjustment for Inflation

Bids for construction submitted to the Owner are good for 90 days. After the contract is signed, the risk of inflation is borne by the Contractor (Ramirez, 2012). Thus, the Owner alleviates the risk of inflation against the initial contract. Inflation may still affect the results of this study as it pertains to final contract amounts. One could argue that differentiating rates of inflation would negate an equal comparison of BOR-approved amounts to TCC and TPC amounts due to inflated or deflated costs throughout the life of any individual project. After careful analysis, and due to the somewhat small size of the construction projects in this study, which often span two to four years in duration, as well as the relatively stagnant economic conditions during the duration of this study's sample, the effects of inflation were assumed to be negligible

Research Findings

The systematic analysis of sample data performed describes the schedule, change order, and budget characteristics of the study sample for each delivery method, and attempts to apply sample findings to the population.

Project Schedule Modification

The Texas A&M University System uses change order days, or the days added to the contractual period between the notice to proceed with construction date and the substantial completion date as a method of tracking the number of calendar days added to the contract for a construction project. To generate a project schedule modification comparison between CMAR and CSP, the observed change order day quantities are directly compared in a representative box plot (see Figure 5). The horizontal lines (see Figure 5) correspond to sample quantiles (see Table 4). The boxplot allows for a side-by-side comparison of the delivery methods by showing the distribution of change order day data as well as identifying outliers.

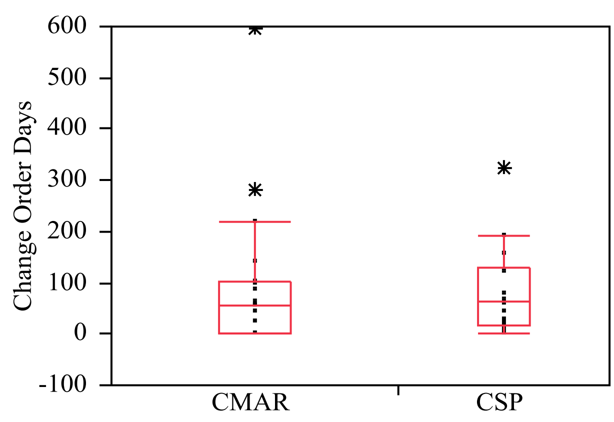

Figure 5. Change order day box plot.

Table 4. *Change order day sample quantiles*

PDM	Minimum	Q1	Median	Q3	Maximum
CMAR	0	0	54	103	597
CSP	0	17.75	64	129	322

Upon review of the box plot (see Figure 5) it can be seen that three outliers exist, which are denoted using stars. Seen in the CMAR sample are two outlying projects, and in the CSP sample, there is one. For the purpose of this study, an outlier is defined as a data point that "is at least 1.5 interquartile ranges below the first quartile (Q1), or at least 1.5 interquartile ranges above the third quartile (Q3)" (Stat Trek, 2012, p.1). To generate an accurate statistical comparison, outlying data points were removed from the scope of schedule growth comparison. After deleting outliers, the remaining data yielded a mean amount of change equal to 52 days for CMAR and 69 days for CSP. The adjusted mean, median, and standard deviation of change order days for each delivery method can be viewed (see Table 5). Outliers aside, data show that out of the sample projects in this study, CMAR procured projects experience a 32% decrease in schedule growth when compared to that of CSP. To further aid in the discussion of CMAR's project schedule modification performance, it should be noted that the ratio of CMAR projects to CSP projects without a single change order is 7:2.

Table 5. Change order day descriptive statistics after outlier removal

PDM	# of projects	Change Order Days	Mean	Median	Standard Deviation
CMAR	17	890	52.35	45	61.79
CSP	13	897	69.00	59	61.51

A two-tailed *t*-test at a 95% level of confidence (α =.05) performed on the data assuming equal variances confirms if the observed difference in means is a product of random sampling. The test of statistical significance yields $t(28)=.733$ and $p=.46$. This suggests that the observed difference in means is not statistically significant; and furthermore, that random sampling from identical populations would lead to a difference in means smaller than observed in 54% of experiments and larger than observed in 46% of experiments (GraphPad, 2012). Thus, it is not appropriate to apply the observed sample means to a population.

Project Change

Sample change order data collection in this study is based on 270 CMAR change orders spread over 19 projects, and 275 CSP change orders spread over 14 projects. Previously explained under the Data Collection section in this paper, each individual project revision within each change order was analyzed in order to yield an accurate representation of project change. A representative box plot (see figure 6) shows number of change orders by delivery method and produces one outlier in the CMAR sample. The horizontal lines (see figure 6) correspond to sample quantiles (see table 6). This correlates to a mean number of project change orders after outlier removal equal to 13.2 contractual revisions per project for CMAR and 19.6 for CSP, and thus, an observed 48% increase in change when using CSP rather than CMAR (see table 7).

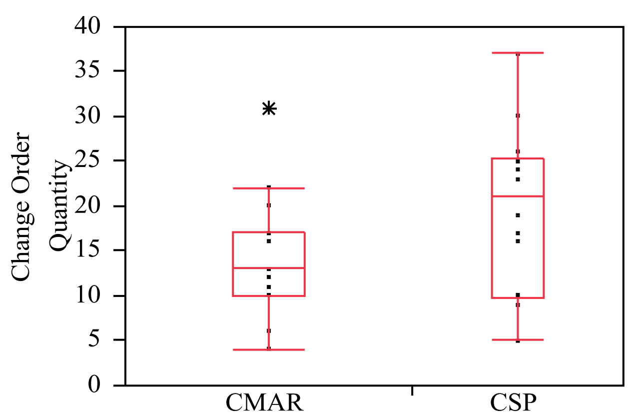

Figure 6. Change order quantity box plot.

Table 6. Change order quantity sample quantiles

PDM	Minimum	Q1	Median	Q3	Maximum
CMAR	4	10	13	17	31
CSP	5	9.75	21	25.25	37

Table 7. Change order quantity descriptive statistics

PDM	# of projects	# of Change Orders	Mean	Median	Standard Deviation
CSP	14	275	19.64	21	9.16
CMAR	19	270	13.21	13	10.00
Total	33	545	16.52	16	8.06

Testing the statistical significance of the difference in change order quantity means after removing the observed outlier, a two-tailed *t*-test assuming equal variances at a 99% level of confidence (α =.05) yields $t(30)=2.49$ and p=.018. The results indicate that the observed difference in change order means is statistically significant. This suggests either that the difference in means is representative of the population, or that the observed difference falls into the 1.8% chance of error category where a significant difference in means does not exist.

To further the discussion of project change, a representative box plot of the quantity of change orders by delivery method per million of TPC (see Appendix D) is presented (see figure 7) showing the study sample's distribution of project change orders per million dollars of TPC. It should be noted that no outliers exist. The horizontal lines (see figure 7) correspond to quantiles (see table 8). CMAR produced a mean of 1.07 contractual changes per million dollars of TPC in comparison to 2.01, or an 87% increase in mean quantity of change per million of TPC for CSP. A two-tailed *t*-test assuming equal variances at a 99% level of confidence (α =.01) performed on the differentiating means yields statistical significance; $t(31)=3.03$ and $p=.0048$. Thus, when comparing CMAR in term of CSP, as the size of a project increases the number of change orders decreases.

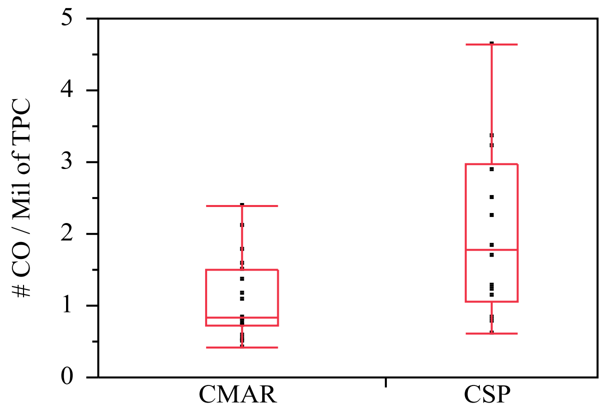

Figure 7. Quantity of change orders per million ($) of TPC box plot.

Table 8. Change orders per million ($) of TPC sample quantiles

PDM	Minimum	Q1	Median	Q3	Maximum
CMAR	0.43	0.71	0.83	1.51	2.4
CSP	0.6	1.055	1.77	2.965	4.64

Analysis of the change order dollar volumes for each of the five Owner stipulated types of change in terms of delivery method selected returns aggregate data (see Appendix E). The data shows that when using CMAR in terms of CSP on a per project basis, that The Texas A&M University System spends 44% more due to User required changes, 97% less due to unforeseen conditions, 76% less due to FP&C required changes, 67% more due to errors and omissions, 42% more on design changes. A side-by-side comparison of change order dollar volume data is useful in identifying trends in each delivery method. To make the comparison, a change order ratio dividing each of the five change order categories total dollar volume per delivery method by the total dollar volume of change for each method is used. An analysis of the change order ratio lends itself to the breakdown of a single dollar spent by The Texas A&M University System divvied up between each of the five change order categories in terms of each delivery method (see figure 8 and figure 9). As an example, for a project in this study procured using CMAR, .43¢ of every dollar spent on change is accredited to the User, in comparison to .29¢ when using CSP. This shows that a dollar spent on change when using CMAR in terms of CSP is 14% more likely to be User required, 4% less likely to be due to an unforeseen condition, 19% less likely due to an FP&C required change, 5% more likely due to an error or omission, and 5% more likely due to a change in design allowing the Owner to identify the likely source of change orders by delivery method prior to construction.

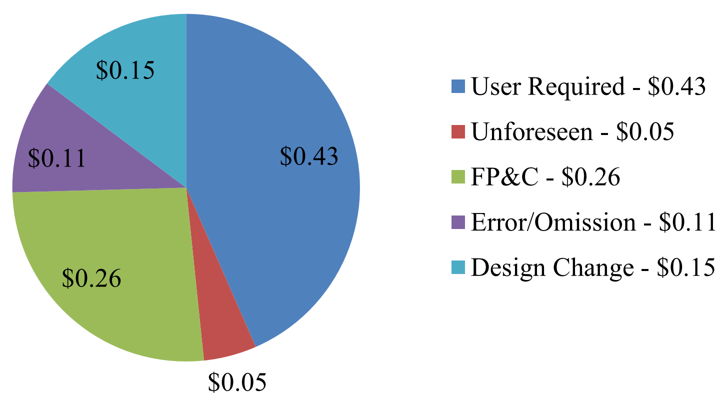

Figure 8. CMAR change order source.

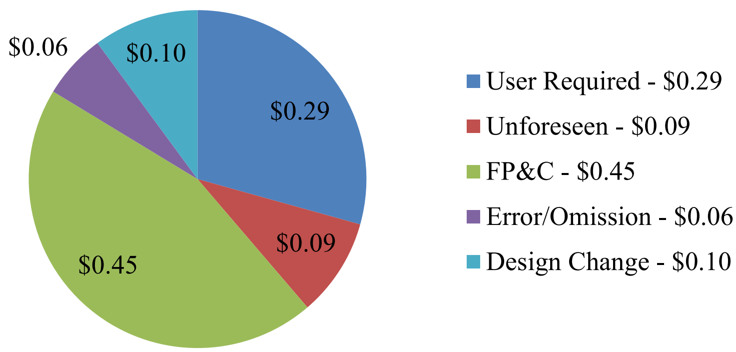

Figure 9. CSP change order source.

Owner Cost Savings

Manipulation of The Texas A&M University System's project data (see Appendix D) reveals fruitful Owner cost savings comparisons (see Appendix F). In order to draw these comparisons, Owner cost savings data are split into two categories: project cost, construction cost. The project cost category tests the performance of the planning amount by subtracting the TPC from the BOR-approved amount. The resulting value displays whether a project's total cost is greater or less than the original allotted amount. This data shows that of the $299.8 million in BOR-approved funds in this sample procured using CMAR, $288.7 million was spent on construction costs, equaling an $11.1 million cost savings. The result is a planning amount performance equal to 3.7% in project cost savings. In comparison, of the $173.5 million in BOR-approved funds in the sample procured using CSP, $164.5 million was spent on construction costs, equaling an $8.9 million cost savings. This translates into a planning amount performance equal to 5.2% in project cost savings, and thus, a 1.5% CSP cost savings increase over that of CMAR.

To make an apples-to-apples comparison and to show statistical significance, a test is performed on the planning amount performance percentage means. The mean percentage represents the savings per dollar of planned expenditure. For example, CMAR's 2.25% mean represents \$.0225 dollars saved per BOR-approved dollar spent, which can then be compared to 3.26% for CSP. After outlier removal, a two-tailed *t*-test assuming equal variances at a 95% level of confidence (α =.05) performed on the differentiating means returns statistical insignificance; $t(28)= .569$ and $p=.57$, indicating that is not appropriate to apply the observed sample means to a population.

To evaluate the difference in construction cost of each delivery method, two AACC performance indicating metrics are used. AACC Performance Indicator #1 measures the performance of the AACC against the GMP for CMAR and the Bid-Amount for CSP. This allows for an evaluation of the Owner-generated AACC prior to the start of construction. AACC Performance Indicator #2 measures the performance of the AACC against the TCC, evaluating the performance of the AACC following construction. CMAR results in a 1% total cost savings as it relates to AACC Performance Indicator #1, compared to a 5.2% total cost savings for CSP (see Appendix F). The observed percentage mean for CMAR after outlier removal equals .108% compared to 8.86% for CSP. This suggests that the use of CSP translates into an increase of \$.087 dollars saved per AACC dollar spent over that of CMAR when analyzing AACC performance prior to construction. A two-tailed *t*-test assuming equal variances at a 90% confidence level (α =.10) performed on the differentiating means after outlier removal returns statistical significance; $t(24)= 1.905$ and $p=.068$. It should be noted that the CMAR sample contained seven outliers, each of which was removed. Analyzing the significance of AACC Performance Indicator #2 results in a CMAR total construction cost loss of 3.8%, a CSP total cost savings of 1.3%, a sample mean CMAR construction cost loss of 4.18% after outlier removal, and a sample mean CSP savings of 4.38% after outlier removal. This indicates that every CSP-AACC dollar spent generates a total construction cost savings equal to \$.013, while every CMAR-AACC dollar spent results in a total construction cost loss of \$.0418. After removing three CMAR sample outliers, a two-tailed *t*-test at a 90% level of confidence (α =.10) performed on the data assuming equal variances shows a statistically significant difference in the post-construction cost savings means of CMAR and CSP; $t(28)= 1.71$ and $p=.098$. Statistical significance testing infers that it may be appropriate to apply the observed sample means to a population.

A histogram (see figure 10) compares the sample means of the Planning Amount Performance, AACC Performance Indicator #1, and AACC Performance Indicator #2 of CMAR and CSP. The figure shows that CSP outperforms CMAR in all three of the project and construction cost performance indicators.

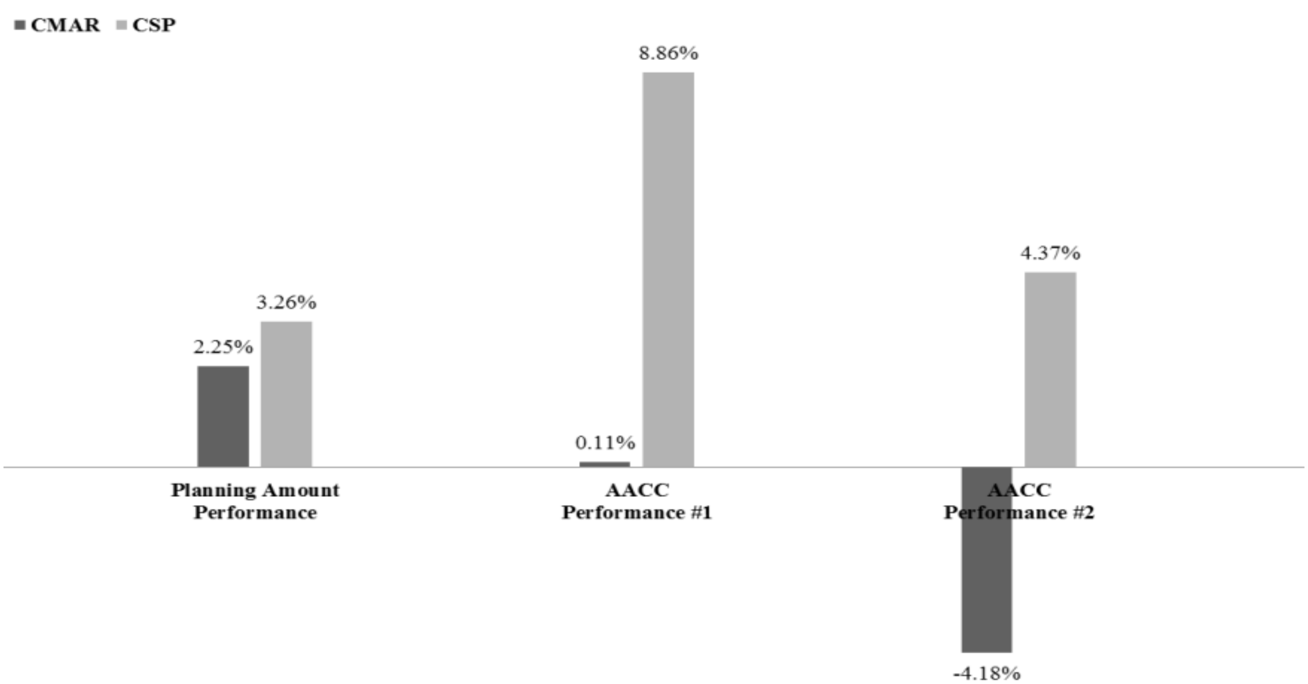

Figure 10. CMAR and CSP budget performance comparison.

Previously discussed in The Texas A&M University System Specific Business Practices section of this thesis under the Job Costs heading, The Texas A&M University System strives to construct the "best" structure possible within the Owner provided AACC. Since the AACC is divulged to Contractors bidding a project for The Texas A&M

University System when using both the CMAR and CSP delivery methods, constructing the “best” structure possible often means that the Owner selects the Contractor that can provide the most “bang for the buck” by providing a CMAR-GMP or CSP bid-amount as close to the AACC as possible. The philosophy is that BOR-approved funds not used in construction are wasted, and thus, it is not in the best interest of the Public or The State of Texas to construct projects at values significantly lower than the AACC (Ramirez, 2012). This may skew Owner cost savings data as well as data analysis results as it is not a goal of the Owner to select Contractors, or to negotiate contracts such that they are significantly below the predetermined AACC.

RESEARCH ASSUMPTIONS AND LIMITATIONS

The fundamental assumption of this research is that the data referenced on IMPACT is accurate. Data is primarily uploaded to IMACT by The Texas A&M University System's Project Managers and employees. It is possible that human errors occurred in the uploading of this data; however, for the purposes of this research all data on IMPACT is assumed to accurately reflect that of the project represented. In addition, a number of variances exist in the data within this study that cannot be valued or explained. Factors such as convenient timing and communication may be to blame for such discrepancies. It must be assumed that the data reflects decisions made in the "best interests" of the Project, User, Owner, Contractor, and State of Texas at the time that they were made (Ramirez, 2012).

The most significant limitation of this study is that the data analyzed is confined to a sample of higher educational construction projects from one university system. For this reason, the conclusions of CMAR and CSP delivery method performance presented in this paper may not accurately represent those of other market segments in the construction industry. Furthermore, other university systems likely vary in the means and methods used to implement either a CMAR or a CSP contract. In addition, the data in this study could be more conclusive with a larger sample size of projects that represented budgetary data with less disparity. The average BOR-approved amount of the CMAR projects in this study equals $15.7 million compared to $12.3 million for CSP. This difference represents a 21% cost difference in CMAR projects over CSP projects, lending to an unequal comparison, with the majority of the larger projects being procured via the CMAR delivery method. A sample with a lower cost difference and a more evenly distributed size of projects between delivery methods would lend increasingly accurate comparisons.

It should also be noted that the nature of construction limits an accurate comparison of multiple projects. The measurement of some factors throughout construction is bound or unquantifiable, such as previous working relationships, personal preferences, quality of communication, or the value of negotiation.

INDUSTRY APPLICATION

Practical application of the research presented in this paper may apply to Owners, Architects, and Contractors alike. In the age of ever-changing methods of procuring a construction project, the selection of a project delivery method is more difficult than ever. The included research identifies key attributes of the CMAR and CSP delivery methods. Data analysis identifies quantitative differences existing between CMAR and CSP. The combination of key attributes and supporting data presented can be utilized to analyze the effects the selection of CMAR or CSP may have on the construction of any higher educational structure; and furthermore, generalized results may be applied to the construction of any project nationwide.

FURTHER RESEARCH INITIATIVES

The researcher has identified the following areas outside the scope of this paper as potential avenues for further research:

- Additional change order research may be executed in order to extrapolate increased findings. One may research the required change order days within each revision in order to associate a time metric with the five Owner stipulated categories of change. This would allow for an analysis of change in terms of contract days, similar to that of the dollar value revision analysis presented in this paper.
- Individual project revisions may be analyzed in order to extract the change order fund dollar values reverted to the Owner. These funds represent a credit to the Owner, which may cloud the results of the change order data in this study. One could then analyze the surpluses of job costs, contingency, or general conditions separately from those of the five change order categories.
- Research may be conducted in order to analyze the front-end selection of alternatives, value engineering, and changes in scope prior to an agreed upon contract amount for construction services. Through interviewing Owner representatives, a researcher may be able to shed light on whether an individual projects contract amount represents a true "hard-bid" amount, or an amount, which includes changes in scope in order to construct the best facility possible within the provided AACC.
- Additional researchers may attempt to administer a qualitative research survey of Users for each completed project. This would allow for additional data in order to conclude whether overall end User satisfaction varies from CMAR to CSP.

CONCLUDING SUMMARY

The construction delivery method research within this paper presents a number of conclusions regarding the project schedule modification, project change, and Owner cost savings of the sample studied. Significant differences in the sample of The Texas A&M University System's projects procured using CMAR and CSP become apparent. Furthermore, a handful of metrics testing the differences in sample means return statistically significant evidence supporting superior performance of one delivery method over the other in terms of construction project change and Owner cost savings.

Although no statistically significant evidence exists in this study supporting either CMAR or CSP as it pertains to the application of schedule growth reduction to a population, the analysis of sample data supports the research hypothesis. The sample distribution of change order days after outlier removal contains a sample mean amount of change equal to 53 days for CMAR with a standard deviation 61.7 days and 69 days for CSP with a standard deviation of 61.5 days. CMAR and CSP are nearly identically distributed around the mean; however, the mean number of change order days for CMAR is 30% lower than that of CSP. This implies that the use of CMAR by The Texas A&M University System results in a 30% reduction in schedule growth when compared to CSP.

This research lends insight into the quantitative performance of CMAR over CSP in terms of revisions to a contract for construction. The study of project change order performance returns a sample size of 545 change orders spread over 33 projects. The 19 CMAR projects yield 270 change orders and the 14 CSP projects yield 275 change orders. Analysis of change order data after the removal of one CMAR sample outlier returns sample means equal to 13.2 for CMAR and 19.6 for CSP. The difference in sample means represents the outperformance of CSP by CMAR through reducing the quantity of contractual revisions per project by 48%. A statistical test of the difference in sample means produces significance at a 99% level of confidence. This supports the research hypothesis, implying that random sampling from identical populations will lead to a difference in means smaller than observed in only 1% of experiments. Further supporting the performance of CMAR over CSP in terms of change, an analysis of change orders per million dollars of TPC was performed. Results produced sample means equal to 1.07 change orders per million dollars of TPC for CMAR and 2.01 for CSP. A test of the differentiating means returned statistical significance at a 99% level of confidence. Thus, when using CSP over CMAR, The Texas A&M University System can expect an 87% increase in quantity of change orders per million dollars of TPC. Results support the generally accepted industry views that the benefits of CMAR grow as the size of a project increases.

The results of this study also support the research hypothesis that the Owners cost savings using CSP is superior to that of CMAR when attempting to achieve optimal project and construction costs. Analysis of sample project cost data show that The Texas A&M University Systems use of CSP results in 3.26% of every BOR-approved dollar being saved upon project completion in comparison to 2.25% for CMAR. Although project cost data returned statistical insignificance, the analysis of construction cost yielded significant results. Research of the AACC's for each method against the CMAR GMP and the CSP Bid-Amount yielded a return of 8.86% of every AACC dollar spent using CSP and .10% for CMAR. Statistically significant results show that it is appropriate to apply the following logic to a population: the use of CSP over CMAR translates to an expected CSP Bid-Amount savings of $.087 per every AACC dollar allotted to a project's construction cost. An analysis of the AACC's for each delivery method against the TPC results in a CSP savings of 4.3% of every AACC dollar spent and a CMAR loss of 4.1%, which can be shown to be statistically significant at a 90% level of confidence. Results show that it is appropriate to apply the additional logic to a population: the use of CSP over CMAR translates to an expected construction cost savings of $.084 per every AACC dollar allotted to a project's cost.

Final research sample conclusions should show that in terms of CMAR, a project constructed by The Texas A&M University System using CSP requires more time in terms of calendar days and a greater amount of contractual revisions; however, project and construction costs are less. Final research population conclusions should show that in terms of CMAR, all projects constructed using CSP should observe an increase in contractual changes, but will observe a reduction in construction costs. The researcher concludes that consistent with the related studies presented within this paper, a Contractor's involvement in design translates into a reduction of contractual changes. Finally, the researcher concludes, similarly to the study performed by (Rojas & Kell, 2008), that a GMP is not effective in guaranteeing the maximum price of a construction project or reducing construction cost growth.

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APPENDIX A

TEXAS PUBLIC EDUCATION STATUE; CSP

§ 44.040. SELECTING CONTRACTOR FOR CONSTRUCTION SERVICES THROUGH COMPETITIVE BIDDING.

(a) Except to the extent prohibited by other law and to the extent consistent with this subchapter, a school district may use competitive bidding to select a contractor to perform construction, rehabilitation, alteration, or repair services for a facility.

(b) Except as otherwise specifically provided by this subsection, Subchapter B, Chapter 271, Local Government Code, does not apply to a competitive bidding process under this subchapter. Sections 271.026, 271.027(a), and 271.0275, Local Government Code, apply to a competitive bidding process under this subchapter.

(c) The district shall select or designate an engineer or architect to prepare construction documents for the project. The selected or designated engineer or architect has full responsibility for complying with Chapter 1001 and Chapter 1051, Occupations Code, as applicable.

(d) A school district shall award a competitively bid contract at the bid amount to the bidder offering the best value to the district according to the selection criteria that were established by the district. The selection criteria may include the factors listed in Section 44.031(b).

Added by Acts 1997, 75th Leg., ch. 1179, § 2, eff. Sept. 1, 1997.
Amended by Acts 1999, 76th Leg., ch. 1225, § 9, eff. Sept. 1, 1999; Acts 2003, 78th Leg., ch. 1229, § 4, eff. Sept. 1, 2003.

APPENDIX B

THE TEXAS PUBLIC EDUCATION STATUTE; CMAR

§ 44.038. CONTRACTS FOR FACILITIES: CONSTRUCTION MANAGER-AT-RISK.

(a) A school district may use the construction manager-at-risk method for the construction, rehabilitation, alteration, or repair of a facility. In using that method and in entering into a contract for the services of a construction manager-at-risk, a district shall follow the procedures prescribed by this section.

(b) A construction manager-at-risk is a sole proprietorship, partnership, corporation, or other legal entity that assumes the risk for construction, rehabilitation, alteration, or repair of a facility at the contracted price as a general contractor and provides consultation to the school district regarding construction during and after the design of the facility.

(c) Before or concurrently with selecting a construction manager-at-risk, the district shall select or designate an engineer or architect who shall prepare the construction documents for the project and who has full responsibility for complying with Chapter 1001 or 1051, Occupations Code, as applicable. If the engineer or architect is not a full-time employee of the district, the district shall select the engineer or architect on the basis of demonstrated competence and qualifications as provided by Section 2254.004, Government Code. The district's engineer, architect, or construction manager-agent for a project may not serve, alone or in combination with another, as the construction manager-at-risk unless the engineer or architect is hired to serve as the construction manager-at-risk under a separate or concurrent procurement conducted in accordance with this subchapter. This subsection does not prohibit the district's engineer or architect from providing customary construction phase services under the engineer's or architect's original professional service agreement in accordance with applicable licensing laws.

(d) The district shall provide or contract for, independently of the construction manager-at-risk, the inspection services, the testing of construction materials engineering, and the verification testing services necessary for acceptance of the facility by the district. The district shall select those services for which it contracts in accordance with Section 2254.004, Government Code.
(e) The district shall select the construction manager-at-risk in either a one-step or two-step process. The district shall prepare a request for proposals, in the case of a one-step process, or a request for qualifications, in the case of a two-step process, that includes general information on the project site, project scope, schedule, selection criteria, estimated budget, and the time and place for receipt of proposals or qualifications, as applicable, a statement as to whether the selection process is a one-step or two-step process, and other information that may assist the district in its selection of a construction manager-at-risk. The district shall state the selection criteria in the request for proposals or qualifications, as applicable. The selection criteria may include the offeror's experience, past performance, safety record, proposed personnel and methodology, and other appropriate factors that demonstrate the capability of the construction manager-at-risk. If a one-step process is used, the district may request, as part of the offeror's proposal, proposed fees and prices for fulfilling the general conditions. If a two-step process is used, the district may not request fees or prices in step one. In step two, the district may request that five or fewer offerors, selected solely on the basis of qualifications, provide additional information, including the construction manager-at-risk's proposed fee and its price for fulfilling the general conditions.
(f) At each step, the district shall receive, publicly open, and read aloud the names of the offerors. At the appropriate step, the district shall also read aloud the fees and prices, if any, stated in each proposal as the proposal is opened. Within 45 days after the date of opening the proposals, the district shall evaluate and rank each proposal submitted in relation to the criteria set forth in the request for proposals.
(g) The district shall select the offeror that submits the proposal that offers the best value for the district based on the published selection criteria and on its ranking

evaluation. The district shall first attempt to negotiate with the selected offeror a contract. If the district is unable to negotiate a satisfactory contract with the selected offeror, the district shall, formally and in writing, end negotiations with that offeror and proceed to negotiate with the next offeror in the order of the selection ranking until a contract is reached or negotiations with all ranked offerors end.

(h) A construction manager-at-risk shall publicly advertise, in accordance with Section 44.031(g), and receive bids or proposals from trade contractors or subcontractors for the performance of all major elements of the work other than the minor work that may be included in the general conditions. A construction manager-at-risk may seek to perform portions of the work itself if the construction manager-at-risk submits its bid or proposal for those portions of the work in the same manner as all other trade contractors or subcontractors and if the district determines that the construction manager-at-risk's bid or proposal provides the best value for the district.

(i) The construction manager-at-risk and the district or its representative shall review all trade contractor or subcontractor bids or proposals in a manner that does not disclose the contents of the bid or proposal during the selection process to a person not employed by the construction manager-at-risk, engineer, architect, or district. All bids or proposals shall be made public after the award of the contract or within seven days after the date of final selection of bids or proposals, whichever is later.

(j) If the construction manager-at-risk reviews, evaluates, and recommends to the district a bid or proposal from a trade contractor or subcontractor but the district requires another bid or proposal to be accepted, the district shall compensate the construction manager-at-risk by a change in price, time, or guaranteed maximum cost for any additional cost and risk that the construction manager-at-risk may incur because of the district's requirement that another bid or proposal be accepted.

(k) If a selected trade contractor or subcontractor defaults in the performance of its work or fails to execute a subcontract after being selected in accordance with this section, the construction manager-at-risk may, without advertising, itself fulfill the contract requirements or select a replacement trade contractor or subcontractor to fulfill the contract requirements.

(l) If a fixed contract amount or guaranteed maximum price has not been determined at the time the contract is awarded, the penal sums of the performance and payment bonds delivered to the district must each be in an amount equal to the project budget, as specified in the request for qualifications. The construction manager shall deliver the bonds not later than the 10th day after the date the construction manager executes the contract unless the construction manager furnishes a bid bond or other financial security acceptable to the district to ensure that the construction manager will furnish the required performance and payment bonds when a guaranteed maximum price is established.

Added by Acts 1997, 75th Leg., ch. 1179, § 2, eff. Sept. 1, 1997.
Amended by Acts 1999, 76th Leg., ch. 1225, § 8, eff. Sept. 1, 1999; Acts 2003, 78th Leg., ch. 1229, § 3, eff. Sept. 1, 2003; Acts 2003, 78th Leg., ch. 1276, § 14A.759, eff. Sept. 1, 2003.

APPENDIX C

TEXAS A&M UNIVERSITY SYSTEM UNIFORM GENRAL AND SUPPLEMENTARY CONDITIONS

10.3.2 Retainage. The Owner will withhold from each progress payment, as retainage, 5 percent of the total earned amount, or the amount authorized by law. Retainage is managed in conformance with Tex. Gov't Code, Chapter 2252, Government Code, subchapter B.

10.3.2.1 The Contractor shall provide written consent of its Surety for any request for reduction or release of retainage.

10.3.2.2 At least sixty-five (65) percent of the total Contract must be completed before the Owner can consider a retainage reduction or release.

APPENDIX D

THE TEXAS A&M UNIVERSITY SYSTEM'S PROJECT DATA

				BUDGET					
Project #		Project Name	Contract	BOR Approved Budget	AACC	GMP	Orgional Project Contingency	TCC	TPC
17	3039	Biology-Earth Sciences Building Renovation	CMAR	$ 4,876,000	$ 3,700,000	$ 3,697,825	$ 400,187	$ 4,054,466	$ 4,742,585
16	2993	Completion Fine Arts Theatre	CMAR	$ 4,944,000	$ 4,077,000	$ 4,043,318	$ 407,700	$ 4,075,431	$ 4,946,997
16	3028	Loop Road and Chill Water Loop	CMAR	$ 7,625,000	$ 4,542,476	$ 4,542,476	$ 1,809,778	$ 6,349,590	$ 7,571,244
17	3005	Citrus Center Building	CMAR	$ 9,540,000	$ 7,200,000	$ 7,197,519	$ 720,000	$ 7,769,822	$ 9,485,148
02	3033	Chemistry Building '72 Wing 4th Floor Renovation	CMAR	$ 9,850,000	$ 7,850,000	$ 7,850,000	$ 785,000	$ 7,756,954	$ 9,370,764
02	3086	Penberthy Field Renovations	CMAR	$ 10,600,000	$ 8,631,934	$ 8,631,934	$ 747,517	$ 9,389,757	$ 10,263,825
04	3003	Dairy Center	CMAR	$ 11,124,000	$ 7,886,800	$ 7,886,800	$ 788,680	$ 9,255,958	$ 11,252,653
02	2977	Chemistry Complex Renovations	CMAR	$ 11,447,736	$ 8,722,579	$ 8,908,568	$ 872,257	$ 8,729,387	$ 10,843,537
17	2950	Recreation Sports Center	CMAR	$ 12,000,000	$ 9,637,100	$ 9,600,000	$ 963,710	$ 9,835,776	$ 11,796,987
02	2962	Lab Animal Resources and Research Facility	CMAR	$ 12,514,680	$ 10,255,000	$ 10,255,093	$ 1,025,500	$ 11,101,101	$ 12,899,219
02	2982	Upgrade of Central Utility Plant and Satellite Utility Plant	CMAR	$ 13,500,000	$ 11,321,000	$ 10,842,498	$ 1,132,100	$ 11,453,618	$ 13,253,400
18	2995	Classroom Center Renovation	CMAR	$ 17,800,000	$ 15,168,416	$ 14,768,416	$ 1,516,841	$ 14,757,533	$ 16,814,902
18	3052	Renovation of Athletic/Intramural Facilities - Phase I	CMAR	$ 21,800,000	$ 16,350,000	$ 17,300,000	$ 1,635,000	$ 17,792,983	$ 20,602,031
02	2986	Cox-McFerrin Center for Aggie Basketball	CMAR	$ 21,879,475	$ 17,252,000	$ 17,981,963	$ 1,725,200	$ 18,469,142	$ 21,838,195
04	3004	Nursing Building	CMAR	$ 24,300,000	$ 15,900,000	$ 15,900,000	$ 1,590,000	$ 14,841,868	$ 20,508,004
15	3013	Michael and Karen O'Connor Building	CMAR	$ 25,000,000	$ 18,749,000	$ 18,749,000	$ 1,874,900	$ 20,267,574	$ 24,963,941
02	2946	Veterinary Research Building Addition	CMAR	$ 25,477,265	$ 14,100,000	$ 15,977,568	$ 1,410,000	$ 20,184,533	$ 23,796,789
16	2994	Student Success Center	CMAR	$ 25,965,000	$ 25,956,946	$ 20,951,788	$ 2,595,694	$ 20,448,439	$ 25,659,624
21	2996	Music Building	CMAR	$ 29,607,000	$ 24,448,440	$ 24,448,440	$ 2,444,844	$ 23,983,141	$ 28,116,512

Project #		Project Name	Contract	BUDGET					
				BOR Approved Budget	AACC	Bid-Amount	Original Project Contingency	TCC	TPC
02	3035	Rehabilitate Runway 10/28	CSP	$ 4,400,000	$ 3,675,000	$ 2,327,038	$ 367,500	$ 2,391,347	$ 2,792,023
02	3027	Veterinary Imaging and Cancer Treatment Center	CSP	$ 4,950,000	$ 3,652,546	$ 3,636,898	$ 386,009	$ 3,985,237	$ 4,761,177
09	2942	Wastewater System Upgrade - Phase I - Brayton Fire Training Field (Package 2)	CSP	$ 17,268,000	$ 13,865,000	$ 12,760,841	$ 1,386,500	$ 13,422,413	$ 16,496,724
15	3050	Utility Plant Expansion	CSP	$ 6,300,000	$ 5,040,000	$ 4,957,778	$ 504,000	$ 5,215,574	$ 6,009,626
02	3018	Zachry Fire & Life Safety Upgrade	CSP	$ 7,000,000	$ 5,415,000	$ 3,106,700	$ 514,500	$ 3,455,967	$ 4,093,821
02	3008	Satellite Utility Plant 1 Chiller Upgrade	CSP	$ 9,600,000	$ 7,930,000	$ 6,329,744	$ 793,000	$ 5,116,309	$ 8,670,569
16	2931	Kinesiology Facility	CSP	$ 12,500,000	$ 10,289,500	$ 10,215,277	$ 1,028,950	$ 10,380,777	$ 12,494,023
04	2938	New Dining Hall	CSP	$ 12,996,000	$ 10,703,500	$ 10,885,061	$ 1,070,350	$ 11,138,691	$ 12,863,143
04	2939	Recreational Sports Facility	CSP	$ 14,520,523	$ 11,130,000	$ 12,123,693	$ 1,212,369	$ 12,444,764	$ 14,999,641
02	3021	YMCA Building Renovation	CSP	$ 15,000,000	$ 10,547,357	$ 7,873,445	$ 659,184	$ 8,998,723	$ 11,957,483
02	2963	Nuclear Magnetic Resonance (NMR) Facility	CSP	$ 15,426,600	$ 10,366,671	$ 10,379,812	$ 1,037,981	$ 12,903,241	$ 15,289,599
04	3002	Central Plant Loop	CSP	$ 15,500,000	$ 12,644,243	$ 12,840,230	$ 1,264,424	$ 12,882,339	$ 14,917,978
12	2920	TTI State Headquarters and Research Building	CSP	$ 18,883,000	$ 15,440,000	$ 15,104,319	$ 1,544,000	$ 15,635,948	$ 18,727,663
22	2928	New Science and Technology Building	CSP	$ 19,190,000	$ 15,600,000	$ 15,811,299	$ 1,560,000	$ 16,565,428	$ 20,516,246

				SCHEDULE	CHANGE ORDER							
Project #		Project Name	Contract	Change Order Days	# of Change Orders	Change Order $ Volume	Change Order $ Volume	Change Order $ Volume	Change Order $ Volume	Change Order $ Volume	Change Order $ Volume	# CO / Mil of TPC
						Required By User	Unforeseen	FP&C Required	Error/Omission	Design Modification	Total	
17	3039	Biology-Earth Sciences Building Renovation	CMAR	0	10	$ 324,709	$ 25,235	$ 18,000	$ -	$ -	$ 367,944	2.11
16	2993	Completion Fine Arts Theatre	CMAR	0	4	$ -	$ -	$ (35,282)	$ -	$ -	$ (35,282)	0.81
16	3028	Loop Road and Chill Water Loop	CMAR	0	6	$ 1,776,105	$ -	$ 298,374	$ -	$ 202,250	$ 2,276,729	0.79
17	3005	Citrus Center Building	CMAR	0	17	$ 462,329	$ 60,297	$ (27,796)	$ -	$ -	$ 494,830	1.79
02	3033	Chemistry Building '72 Wing 4th Floor Renovation	CMAR	281	11	$ 86,959	$ 96,291	$ (228,563)	$ 6,742	$ -	$ (38,571)	1.17
02	3086	Penberthy Field Renovations	CMAR	0	6	$ 694,435	$ 11,410	$ (3,388)	$ 37,498	$ -	$ 739,955	0.58
04	3003	Dairy Center	CMAR	54	17	$ 66,277	$ 250,000	$ 102,568	$ 891,215	$ -	$ 1,310,060	1.51
02	2977	Chemistry Complex Renovations	CMAR	597	17	$ -	$ 36,943	$ (679,662)	$ -	$ 941,725	$ 299,006	1.57
17	2950	Recreation Sports Center	CMAR	0	16	$ 183,816	$ 83,335	$ 466,501	$ -	$ 184,742	$ 918,394	1.36
02	2962	Lab Animal Resources and Research Facility	CMAR	64	31	$ 473,707	$ 244,297	$ 767,946	$ 46,211	$ 95,707	$ 1,627,868	2.40
02	2982	Upgrade of Central Utility Plant and Satellite Utility Plant	CMAR	45	11	$ -	$ -	$ 1,061,264	$ -	$ 287,236	$ 1,348,500	0.83
18	2995	Classroom Center Renovation	CMAR	217	12	$ 293,358	$ 16,644	$ (417,253)	$ -	$ 157,288	$ 50,037	0.71
18	3052	Renovation of Athletic/Intramural Facilities - Phase I	CMAR	85	10	$ 69,902	$ 58,207	$ 318,499	$ -	$ -	$ 446,608	0.49
02	2986	Cox-McFerrin Center for Aggie Basketball	CMAR	57	16	$ 304,765	$ 11,594	$ 1,521,698	$ -	$ 242,191	$ 2,080,248	0.73
04	3004	Nursing Building	CMAR	25	22	$ (862,794)	$ -	$ (269,796)	$ 366,179	$ -	$ (766,411)	1.07
15	3013	Michael and Karen O'Connor Building	CMAR	97	13	$ 723,789	$ 19,910	$ 103,991	$ 681,221	$ 50,000	$ 1,578,911	0.52
02	2946	Veterinary Research Building Addition	CMAR	143	20	$ 4,216,338	$ (52,000)	$ 891,087	$ -	$ 220,999	$ 5,276,424	0.84
16	2994	Student Success Center	CMAR	0	11	$ (580,114)	$ -	$ 253,738	$ -	$ 321,884	$ (4,492)	0.43
21	2996	Music Building	CMAR	103	20	$ 232,723	$ 97,792	$ 965,899	$ 49,240	$ 174,727	$ 1,520,381	0.71

				SCHEDULE	CHANGE ORDER							
Project #		Project Name	Contract	Change Order Days	# of Change Orders	Change Order $ Volume	Change Order $ Volume	Change Order $ Volume	Change Order $ Volume	Change Order $ Volume	Change Order $ Volume	# CO / Mil of TPC
						Required By User	Unforeseen	FP&C Required	Error/Omission	Design Modification	Total	
02	3035	Rehabilitate Runway 10/28	CSP	191	9	$ 78,806	$ 179,274	$ (112,065)	$ 2,380	$ -	$ 148,395	3.22
02	3027	Veterinary Imaging and Cancer Treatment Center	CSP	21	16	$ 169,120	$ 57,991	$ 109,355	$ 96,499	$ -	$ 432,965	3.36
09	2942	Wastewater System Upgrade - Phase I - Brayton Fire Training Field (Package 2)	CSP	119	37	$ 444,121	$ 130,434	$ 1,175,546	$ 24,672	$ 71,155	$ 1,845,928	2.24
15	3050	Utility Plant Expansion	CSP	0	5	$ 177,868	$ 42,472	$ -	$ 37,456	$ -	$ 257,796	0.83
02	3018	Zachry Fire & Life Safety Upgrade	CSP	30	19	$ 305,580	$ 142,446	$ 19,595	$ 14,088	$ -	$ 481,709	4.64
02	3008	Satellite Utility Plant 1 Chiller Upgrade	CSP	322	25	$ 278,992	$ 73,452	$ 17,512	$ 347,554	$ 11,600	$ 729,110	2.88
16	2931	Kinesiology Facility	CSP	59	23	$ -	$ -	$ 719,017	$ -	$ 14,237	$ 733,254	1.84
04	2938	New Dining Hall	CSP	45	10	$ 58,452	$ 37,122	$ 426,727	$ -	$ 135,529	$ 657,830	0.78
04	2939	Recreational Sports Facility	CSP	8	17	$ -	$ -	$ 830,775	$ -	$ 113,947	$ 944,722	1.13
02	3021	YMCA Building Renovation	CSP	156	30	$ 537,010	$ 414,416	$ 86,921	$ 156,595	$ -	$ 1,194,942	2.51
02	2963	Nuclear Magnetic Resonance (NMR) Facility	CSP	69	26	$ 2,182,499	$ 175,389	$ 414,244	$ 104,423	$ 621,611	$ 3,498,166	1.70
04	3002	Central Plant Loop	CSP	0	9	$ (27,630)	$ 17,197	$ 135,165	$ 51,302	$ -	$ 176,034	0.60
12	2920	TTI State Headquarters and Research Building	CSP	120	24	$ 112,867	$ 92,426	$ 856,278	$ 82,486	$ 510,577	$ 1,654,634	1.28
22	2928	New Science and Technology Building	CSP	79	25	$ -	$ 22,180	$ 1,940,018	$ -	$ 8,583	$ 1,970,781	1.22

APPENDIX E

AGGREGATE PROJECT CHANGE DATA

User Required						
PDM	**# of projects**	**Total $ Volume**	**Mean**	**Median**	**SD**	**CO Ratio**
CSP	14	$4,317,685	$308,406	$140,994	$566,495	$0.29
CMAR	19	$8,466,304	$445,595	$232,723	$1,056,038	$0.43

Unforeseen Conditions						
PDM	**# of projects**	**Total $ Volume**	**Mean**	**Median**	**SD**	**CO Ratio**
CSP	14	$1,384,799	$98,914	$65,722	$109,628	$0.09
CMAR	19	$959,955	$50,524	$19,910	$78,926	$0.05

FP&C Required						
PDM	**# of projects**	**Total $ Volume**	**Mean**	**Median**	**SD**	**CO Ratio**
CSP	14	$6,619,088	$472,792	$274,705	$579,206	$0.45
CMAR	19	$5,107,825	$268,833	$103,991	$559,894	$0.26

Error/Omission						
PDM	**# of projects**	**Total $ Volume**	**Mean**	**Median**	**SD**	**CO Ratio**
CSP	14	$917,455	$65,533	$31,064	$94,893	$0.06
CMAR	19	$2,078,306	$109,385	$0	$255,070	$0.11

Design Change						
PDM	**# of projects**	**Total $ Volume**	**Mean**	**Median**	**SD**	**CO Ratio**
CSP	14	$1,487,239	$106,231	$10,092	$201,136	$0.10
CMAR	19	$2,878,749	$151,513	$95,707	$221,892	$0.15

APPENDIX F

OWNER COST SAVINGS COMPARISON DATA

Project #		Project Name	Contract	Project Cost				Construction Cost						
				Project Budget	Total Project Cost	Planning Amount Performance	Planning Amount Performance	AACC	CMAR GMP / CSP Bid-Amount	AACC Performance #1	AACC Performance #1	TCC	AACC Performance #2	AACC Performance #2
				BOR Approved		BOR - TPC	Savings / Loss			AACC - GMP/Bid	Savings / Loss		AACC - TCC	Savings / Loss
17	3039	Biology-Earth Sciences Building Renovation	CMAR	$ 4,876,000	$ 4,742,585	$ 133,415	2.7%	$ 3,700,000	$ 3,697,825	$ 2,175	0.1%	$ 4,054,466	$ (354,466)	-9.6%
16	2993	Completion Fine Arts Theatre	CMAR	$ 4,944,000	$ 4,946,997	$ (2,997)	-0.1%	$ 4,077,000	$ 4,043,318	$ 33,682	0.8%	$ 4,075,431	$ 1,569	0.0%
16	3028	Loop Road and Chill Water Loop	CMAR	$ 7,625,000	$ 7,571,244	$ 53,756	0.7%	$ 4,542,476	$ 4,542,476	$ -	0.0%	$ 6,349,590	$ (1,807,114)	-39.8%
17	3005	Citrus Center Building	CMAR	$ 9,540,000	$ 9,485,148	$ 54,852	0.6%	$ 7,200,000	$ 7,197,519	$ 2,481	0.0%	$ 7,769,822	$ (569,822)	-7.9%
02	3033	Chemistry Building '72 Wing 4th Floor Renovation	CMAR	$ 9,850,000	$ 9,370,764	$ 479,236	4.9%	$ 7,850,000	$ 7,850,000	$ -	0.0%	$ 7,756,954	$ 93,046	1.2%
02	3086	Penberthy Field Renovations	CMAR	$ 10,600,000	$ 10,263,825	$ 336,175	3.2%	$ 8,631,934	$ 8,631,934	$ -	0.0%	$ 9,389,757	$ (757,823)	-8.8%
04	3003	Dairy Center	CMAR	$ 11,124,000	$ 11,252,653	$ (128,653)	-1.2%	$ 7,886,800	$ 7,886,800	$ -	0.0%	$ 9,255,958	$ (1,369,158)	-17.4%
02	2977	Chemistry Complex Renovations	CMAR	$ 11,447,736	$ 10,843,537	$ 604,199	5.3%	$ 8,722,579	$ 8,908,568	$ (185,989)	-2.1%	$ 8,729,387	$ (6,808)	-0.1%
17	2950	Recreation Sports Center	CMAR	$ 12,000,000	$ 11,796,987	$ 203,013	1.7%	$ 9,637,100	$ 9,600,000	$ 37,100	0.4%	$ 9,835,776	$ (198,676)	-2.1%
02	2962	Lab Animal Resources and Research Facility	CMAR	$ 12,514,680	$ 12,899,219	$ (384,539)	-3.1%	$ 10,255,000	$ 10,255,093	$ (93)	0.0%	$ 11,101,101	$ (846,101)	-8.3%
02	2982	Upgrade of Central Utility Plant and Satellite Utility Plant	CMAR	$ 13,500,000	$ 13,253,400	$ 246,600	1.8%	$ 11,321,000	$ 10,842,498	$ 478,502	4.2%	$ 11,453,618	$ (132,618)	-1.2%
18	2995	Classroom Center Renovation	CMAR	$ 17,800,000	$ 16,814,902	$ 985,098	5.5%	$ 15,168,416	$ 14,768,416	$ 400,000	2.6%	$ 14,757,533	$ 410,883	2.7%
18	3052	Renovation of Athletic/Intramural Facilities - Phase I	CMAR	$ 21,800,000	$ 20,602,031	$ 1,197,969	5.5%	$ 16,350,000	$ 17,300,000	$ (950,000)	-5.8%	$ 17,792,983	$ (1,442,983)	-8.8%
02	2986	Cox-McFerrin Center for Aggie Basketball	CMAR	$ 21,879,475	$ 21,838,195	$ 41,280	0.2%	$ 17,252,000	$ 17,981,963	$ (729,963)	-4.2%	$ 18,469,142	$ (1,217,142)	-7.1%
04	3004	Nursing Building	CMAR	$ 24,300,000	$ 20,508,004	$ 3,791,996	15.6%	$ 15,900,000	$ 15,900,000	$ -	0.0%	$ 14,841,868	$ 1,058,132	6.7%
15	3013	Michael and Karen O'Connor Building	CMAR	$ 25,000,000	$ 24,963,941	$ 36,059	0.1%	$ 18,749,000	$ 18,749,000	$ -	0.0%	$ 20,267,574	$ (1,518,574)	-8.1%
02	2946	Veterinary Research Building Addition	CMAR	$ 25,477,265	$ 23,796,789	$ 1,680,476	6.6%	$ 14,100,000	$ 15,977,568	$ (1,877,568)	-13.3%	$ 20,184,533	$ (6,084,533)	-43.2%
16	2994	Student Success Center	CMAR	$ 25,965,000	$ 25,659,624	$ 305,376	1.2%	$ 25,956,946	$ 20,951,788	$ 5,005,158	19.3%	$ 20,448,439	$ 5,508,507	21.2%
21	2996	Music Building	CMAR	$ 29,607,000	$ 28,116,512	$ 1,490,488	5.0%	$ 24,448,440	$ 24,448,440	$ -	0.0%	$ 23,983,141	$ 465,299	1.9%
		CMAR Total		$ 299,850,156	$ 288,726,357	$ 11,123,799	3.7%	$ 231,748,691	$ 229,533,206	$ 2,215,485	1.0%	$ 240,517,073	$ (8,768,382)	-3.8%
		CMAR Mean		$ 15,781,587	$ 15,196,124	$ 585,463	2.96%	$ 12,197,300	$ 12,080,695	$ 116,604	0.10%	$ 12,658,793	$ (461,494)	-6.76%
		CMAR Median		$ 12,514,680	$ 12,899,219	$ 246,600	1.83%	$ 10,255,000	$ 10,255,093	$ -	0.00%	$ 11,101,101	$ (354,466)	-7.06%
		CMAR Standard deviation		$ 7,811,783	$ 7,334,916	$ 954,868	4.04%	$ 6,439,326	$ 6,051,594	$ 1,294,861	5.92%	$ 6,044,922	$ 2,076,855	14.69%
02	3035	Rehabilitate Runway 10/28	CSP	$ 4,400,000	$ 2,792,023	$ 1,607,977	36.5%	$ 3,675,000	$ 2,327,038	$ 1,347,962	36.7%	$ 2,391,347	$ 1,283,653	34.9%
02	3027	Veterinary Imaging and Cancer Treatment Center	CSP	$ 4,950,000	$ 4,761,177	$ 188,823	3.8%	$ 3,652,546	$ 3,636,898	$ 15,648	0.4%	$ 3,985,237	$ (332,691)	-9.1%
09	2942	Wastewater System Upgrade - Phase I - Brayton Fire Training Field (Package 2)	CSP	$ 17,268,000	$ 16,496,724	$ 771,276	4.5%	$ 13,865,000	$ 12,760,841	$ 1,104,159	8.0%	$ 13,422,413	$ 442,587	3.2%
15	3050	Utility Plant Expansion	CSP	$ 6,300,000	$ 6,009,626	$ 290,374	4.6%	$ 5,040,000	$ 4,957,778	$ 82,222	1.6%	$ 5,215,574	$ (175,574)	-3.5%
02	3018	Zachry Fire & Life Safety Upgrade	CSP	$ 7,000,000	$ 4,093,821	$ 2,906,179	41.5%	$ 5,415,000	$ 3,106,700	$ 2,308,300	42.6%	$ 3,455,967	$ 1,959,033	36.2%
02	3008	Satellite Utility Plant 1 Chiller Upgrade	CSP	$ 9,600,000	$ 8,670,569	$ 929,431	9.7%	$ 7,930,000	$ 6,329,744	$ 1,600,256	20.2%	$ 5,116,309	$ 2,813,691	35.5%
16	2931	Kinesiology Facility	CSP	$ 12,500,000	$ 12,494,023	$ 5,977	0.0%	$ 10,289,500	$ 10,215,277	$ 74,223	0.7%	$ 10,380,777	$ (91,277)	-0.9%
04	2938	New Dining Hall	CSP	$ 12,996,000	$ 12,863,143	$ 132,857	1.0%	$ 10,703,500	$ 10,885,061	$ (181,561)	-1.7%	$ 11,138,691	$ (435,191)	-4.1%
04	2939	Recreational Sports Facility	CSP	$ 14,520,523	$ 14,999,641	$ (479,118)	-3.3%	$ 11,130,000	$ 12,123,693	$ (993,693)	-8.9%	$ 12,444,764	$ (1,314,764)	-11.8%
02	3021	YMCA Building Renovation	CSP	$ 15,000,000	$ 11,957,483	$ 3,042,517	20.3%	$ 10,547,357	$ 7,873,445	$ 2,673,912	25.4%	$ 8,998,723	$ 1,548,634	14.7%
02	2963	Nuclear Magnetic Resonance (NMR) Facility	CSP	$ 15,426,600	$ 15,289,599	$ 137,001	0.9%	$ 10,366,671	$ 10,379,812	$ (13,141)	-0.1%	$ 12,903,241	$ (2,536,570)	-24.5%
04	3002	Central Plant Loop	CSP	$ 15,500,000	$ 14,917,978	$ 582,022	3.8%	$ 12,644,243	$ 12,840,230	$ (195,987)	-1.6%	$ 12,882,339	$ (238,096)	-1.9%
12	2920	TTI State Headquarters and Research Building	CSP	$ 18,883,000	$ 18,727,663	$ 155,337	0.8%	$ 15,440,000	$ 15,104,319	$ 335,681	2.2%	$ 15,635,948	$ (195,948)	-1.3%
22	2928	New Science and Technology Building	CSP	$ 19,190,000	$ 20,516,246	$ (1,326,246)	-6.9%	$ 15,600,000	$ 15,811,299	$ (211,299)	-1.4%	$ 16,565,428	$ (965,428)	-6.2%
		CSP Total		$ 173,534,123	$ 164,589,716	$ 8,944,407	5.2%	$ 136,298,817	$ 128,352,135	$ 7,946,682	5.8%	$ 134,536,758	$ 1,762,059	1.3%
		CSP Mean		$ 12,395,295	$ 11,756,408	$ 638,886	8.37%	$ 9,735,630	$ 9,168,010	$ 567,620	8.86%	$ 9,609,768	$ 125,861	4.38%
		CSP Median		$ 13,758,262	$ 12,678,583	$ 239,599	3.78%	$ 10,457,014	$ 10,297,545	$ 78,223	1.18%	$ 10,759,734	$ (185,761)	-1.58%
		CSP Standard deviation		$ 5,083,421	$ 5,637,561	$ 1,194,230	14.45%	$ 4,061,068	$ 4,485,923	$ 1,066,741	15.86%	$ 4,749,429	$ 1,395,156	18.89%
		# of outliers		-	-	-	CMAR (1) CSP (2)	-	-	-	CMAR (7) CSP (0)	-	-	CMAR (3) CSP (0)
		Adjusted CMAR Sample mean w/o outliers		-	-	-	2.250%	-	-	-	0.108%	-	-	-4.180%
		Adjusted CSP sample mean w/o outliers		-	-	-	3.260%	-	-	-	8.864%	-	-	4.370%
		p -value w/o outliers assuming equal variances		-	-	-	0.5737	-	-	-	0.0688	-	-	0.0981