9-25-2003

An Evaluation of Public Construction Contracting Methods for the Public Building Sector in Oregon using Data Envelopment Analysis

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DISSERTATION APPROVAL

The abstract and dissertation of Gerald Herman Williams, Jr. for the Doctor of Philosophy in Systems Science: Engineering Management were presented September 25, 2003, and accepted by the dissertation committee and the doctoral program.

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ABSTRACT

An abstract of the dissertation of Gerald Herman Williams, Jr. for the Doctor of Philosophy in Systems Science: Engineering Management presented September 25, 2003.

Title: An Evaluation of Public Construction Contracting Methods for the Public Building Sector in Oregon using Data Envelopment Analysis

Since 1976 public agencies in Oregon have been allowed to select construction contractors using a "qualification" based competition instead of the more typical lowest responsible bid or Design-Bid-Build (DBB) basis. Since 1985, at least 136 such selections, commonly known as CM/GC for Construction Manager/General Contractor, have been made. The results of this policy have not previously been analyzed. This research compares these selection methods, seeking to answer the following questions:

1. Does the CM/GC method result in projects that differ from DBB projects regarding cost and schedule control?
2. Are CM/GC projects more *efficient* than DBB projects, where efficiency is defined as the data envelopment analysis (DEA) technical efficiency score?
3. Does efficiency depend on an interaction between project type and the selection method?
4. How do project stakeholders evaluate the benefits and drawbacks of the two selection methods?

5. How do projects compare when the only apparent difference between them is the selection method?

To answer these questions, we identified 407 Oregon public building construction projects and obtained a variety of data, including cost and schedule results, for 215 jobs (111 CM/GC and 104 DBB). We analyzed the data several ways, including statistical analysis, DEA, and various qualitative methods.

Results:

1. There was no statistically significant difference between the CM/GC and DBB projects regarding cost and schedule control.
2. The DEA technical efficiency scores showed that CM/GC projects outperformed the DBB projects.
3. There was no interaction effect between project type and selection method.
4. Project stakeholders stated that reduction of risk is the principal benefit of using CM/GC; however, architects and subcontractors are less enthusiastic than owners and general contractors.
5. Data on two nearly identical projects indicated that the DBB project was less costly than the comparable CM/GC project and also incurred less cost growth; both projects were completed on time.

To summarize, this research fails to find support for the current Oregon law that exempts certain projects from competitive bidding based on the presumption that CM/GC will lead to substantial cost savings but does indicate that the CM/GC projects may be better able to accommodate accelerated project schedules.

AN EVALUATION OF PUBLIC CONSTRUCTION CONTRACTING METHODS FOR THE PUBLIC BUILDING SECTOR IN OREGON USING DATA ENVELOPMENT ANALYSIS

by

GERALD HERMAN WILLIAMS, JR.

A dissertation submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY
in
SYSTEM SCIENCE: ENGINEERING MANAGEMENT

Portland State University

DEDICATION

To my wife Caroline and daughters Gwyneth and Gillian.

ACKNOWLEDGMENTS

This dissertation would not have been possible without the advice and guidance of my committee chair Dr. Timothy R. Anderson and committee members, Dr. Wayne W. Wakeland, Dr. David F. Rogge, Dr. Dragan Z. Milosevic, and Graduate Studies Representative Dr. Robert R. Harmon.

Appendix B contains the names of the members of the Expert Panel and others that played an instrumental role in aiding in the data collection and by providing their insights by way of the stakeholder survey responses. I would especially like to thank Bart Eberwein of Hoffman Construction and Joe Bolkovatz of JE Dunn for their extensive contributions in every aspect of this research.

I want to acknowledge a group of people, without whom I would never have come to this place in my life. First among them is my father, Gerry Williams, AIA, an architect who prided himself on his building construction knowledge; he died one month and one day after the proposal for this work was approved. Hugh Langton, PE, Tom Tye, PE, and Jim Smith, SE/PE; three engineers I grew up knowing; they, as much as anyone inspired me to study civil engineering. Like my father, Tom and Jim both passed in 1998 and they are greatly missed.

John Storrs, AIA, an incredibly talented and renowned architect, was my first boss and served as a member of my Expert Panel; he helped to start me on this path and remained a friend until his recent passing in September. Many others that have helped and guided me along my professional path, including: Bob Wright, PE, Mike

Soderquist, PE, Glen Grant, PE, Pat LaCrosse, Brian McCarl, Joe Bolkovatz, Jim Redfield, Franklin Drake, and Roger Brown.

The faculty and staff of Portland State University, and most importantly Dr. Dundar Kocaoglu, our department chair, without whom, I would never have been able to pursue this research. Dean Robert Dryden, who constantly encouraged me to complete this work; and, Dr. Harold Lindstone, the founder of the Systems Science program at PSU, who inspired me to pursue my academic career there.

Lastly, to the staff members who helped refine my presentation, edit and re-edit and retype this dissertation, Ann White, Lori Lachman, Kim Dorris and most importantly, Sharon Peterson, who will have read and reread this dissertation more than any other person, save myself.

Gerry Williams

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1 Introduction and Scope of Research

This research was conducted in accordance with the rules established by the office of Graduate Studies and Research, Portland State University, in order to satisfy requirements for the Doctor of Philosophy in System Science: Engineering & Technology Management. The scope of the research was approved by the dissertation committee with minor deviations approved by the committee chairman as allowed by the university. All data used in the analysis and this research was "public information" except opinions and comments elicited from construction experts and project personnel regarding project performance summarized in Chapter 5.

1.1 Purpose, Research Questions and Hypotheses

The principle purpose of this research is to determine if the different project delivery systems result in better projects and to determine if the public policy that allows public agencies in Oregon to use qualifications based selection processes for construction contractors, instead of the traditional lowest responsible bidder method is justified.

The second objective is to determine if there are "best uses" of the different contracting methods and establish a method for comparing construction project performance using Data Envelopment Analysis (DEA). To meet the objectives five research questions have been formulated:

1. Do negotiated, performance based contractor selected projects outperform the traditional competitively bid projects?
2. Are negotiated projects more efficient than bid projects?

3. Are there best practices for the specific PDS's? That is, is one PDS better for a specific project type than the other?

4. What are the benefits and drawbacks of the two methods according to the principal project stakeholders? Are all the stakeholders' views consistent with each other, and supported by the data analysis? What insights into how these policy decisions are made can be drawn from the stakeholders and are these consistent with the data analysis?

5. Are cases studies of projects and comparisons of similar projects that use different contracting methods consistent with the data analysis?

In order to answer these questions, the following research hypotheses have been formulated:

> H_{A1}: Negotiated Procurement, Construction Manager/General Contractor (CM/GC) method of Project Delivery System (PDS) results in projects that outperform the traditional Design-Bid-Build (DBB) PDS method on cost and schedule control metrics.
>
> H_{01}: There is no significant difference between CM/GC and DBB projects with respect to cost and schedule control metrics.

> H_{A2}: CM/GC projects are more efficient than DBB projects, where efficiency is defined by a DEA model that considers both inputs and outputs from the construction process model.
>
> H_{02}: There is no significant difference between CM/GC and DBB projects with respect to efficiency scores where efficiency is determined by a DEA model that considers both inputs and outputs from the construction process model.

H_{A3}: CM/GC PDS results in projects that outperform DBB PDS on similar types of projects.

$H_{A3.1}$: When applied to corrections projects, CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.2}$: When applied to hospital projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.3}$: When applied to institutional projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.4}$: When applied to library projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.5}$: When applied to office building projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.6}$: When applied to parking structure projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.7}$: When applied to building remodel projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.8}$: When applied to school projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.9}$: When applied to sports facility projects CM/GC PDS results in projects that outperform DBB PDS projects.

H_{03}: CM/GC PDS does not result in projects that outperform DBB PDS on similar types of projects.

(Note the sub-hypotheses of the null hypothesis H_{03} are omitted for brevity.)

1.2 Research Design and Data Collection

How is "outperformed" determined? Or, more generally, how is performance determined, what measures are used, and where does the required information come from? Clearly, performance can be defined in a number of ways and use any number of metrics or measures. Sanvido [182] Chua [47, 48] and others have laid some of the groundwork by providing critical project success factors, while Knuf, [123] Hanna, [104] Russell, [177] and others have contributed benchmarking metrics. These can be thought of as inputs and outputs to a construction project management model. However, the number of metrics and measures provided in the literature is quite large, and therefore only the most important measures must be separated out from those of lesser importance for this analysis.

The process undertaken in this research started with assembling a panel of construction industry experts (referred to hereafter as the Expert Panel), which is detailed in Chapter 3. Metrics were elicited from the Expert Panel consistent with methods described by Ayyub [13], Chua [48] and Kocaoglu [124].

Data was obtained on a 407 public projects constructed in Oregon from 1986 to 2002 (the "Oregon database"). One hundred and ninety-two of the projects either did not meet the criteria for the analysis or had significant missing data, which made them unusable in the model. Two hundred and fifteen projects were used in the final DEA model and analysis. These were nearly equally distributed between competitive lump sum Design-Bid-Build (DBB) and negotiated Construction Manager/General Contractor (CM/GC) Project Delivery Systems (PDS) at 104 and 111 respectively.

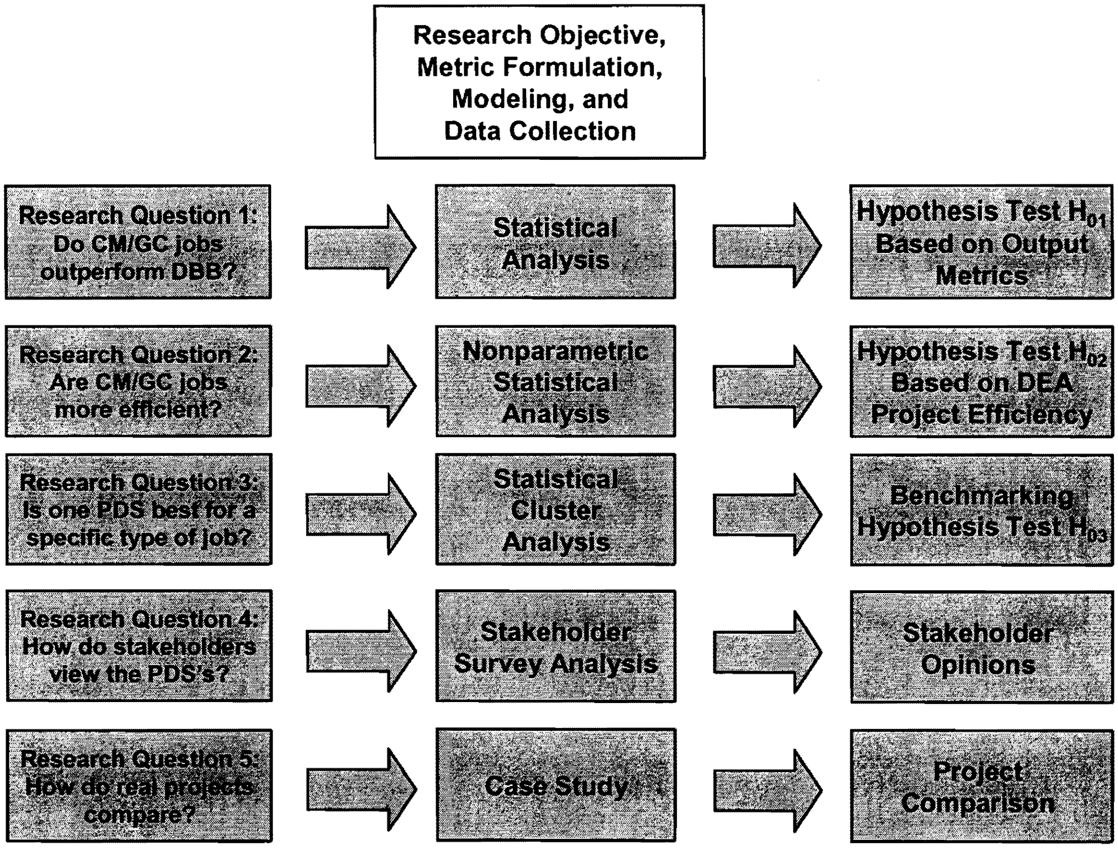

Figure 1: Research design

1.2.1 Research Objective

The research objective of this study is to determine if the public policy, allowing public agencies to select construction contractors on past performance and proposal basis, instead of lowest responsible competitive price basis, should be continued.

1.2.2 Research Question 1; PDS Performance - Statistical Analysis of Output

The first research question is to determine if CM/GC projects outperform DBB jobs. For this analysis we apply a simple statistical analysis on the output metrics, cost and schedule control to test the hypothesis:

> H_{A1}: Negotiated Procurement, Construction Manager/General Contractor (CM/GC) method of Project Delivery System (PDS) results in projects that outperform the traditional Design-Bid-Build (DBB) PDS method on cost and schedule control metrics.
>
> H_{01}: There is no significant difference between CM/GC and DBB projects with respect to cost and schedule control metrics.

1.2.3 Research Question 2; Project Efficiency - Nonparametric Statistical Analysis

The second research question is to determine if CM/GC projects are more technically efficient than DBB jobs. Since DEA is a non-parametric method that results in efficiency scores that are distinctly non-normally distributed, non-parametric statistical analysis is the appropriate method to use in hypothesis testing of DEA model scores. DEA models both inputs and outputs and results in an overall score of project technical efficiency. Here we test the hypothesis:

H_{A2}: CM/GC projects are more efficient than DBB projects, where efficiency is defined by a DEA model that considers both inputs and outputs from the construction process model.

H_{02}: There is no significant difference between CM/GC and DBB projects with respect to efficiency scores where efficiency is determined by a DEA model that considers both inputs and outputs from the construction process model.

1.2.4 Research Question 3: Benchmarking - Cluster & Statistical Analysis

Is there one type of project that is better suited to a particular PDS? A cluster analysis on DEA weights is used to determine if projects that use different PDS also use different weighting schemes and test the hypotheses:

H_{A3}: CM/GC PDS results in projects that outperform DBB PDS on similar types of projects.

$H_{A3.1}$: When applied to corrections projects, CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.2}$: When applied to hospital projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.3}$: When applied to institutional projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.4}$: When applied to library projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.5}$: When applied to office building projects CM/GC PDS results in projects that outperform DBB PDS projects.

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$H_{A3.8}$: When applied to school projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.9}$: When applied to sports facility projects CM/GC PDS results in projects that outperform DBB PDS projects.

H_{03}: CM/GC PDS does not result in projects that outperform DBB PDS on similar types of projects.

(Note the sub-hypotheses of the null hypothesis H03 are omitted for brevity.)

1.2.5 Research Question 4: Stakeholder Analysis

The fourth research question is an evaluation of the PDS's based on the opinions of practitioners. This evaluation is more complex than the previous research questions because we seek to determine why practitioners like or dislike the PDS's, what justifies the choice of PDS, and if there are significant differences between project stakeholders on these issues?

Beierly, [23] Ayyub [13] and others have demonstrated the value of stakeholder opinion. The stakeholder analysis was designed to find out how decisions were being made by practitioners in the field with respect to the choice of PDS. In particular, the intent is to determine if different stakeholders hold different views on the processes and to determine if the stakeholders' opinions support or contradict the data analysis.

1.2.6 Research Question 5; Project Comparison Case Study

The fifth research question involves finding comparable projects that use different PDS's. Then making qualitative and quantitative comparisons to confirm or refute the data analysis. According to the stated public policy, CM/GC projects must result in substantial savings to the public agency, therefore, if two projects were sufficiently similar, the CM/GC project should always cost less than the DBB job.

Secondly, does the comparison lead to further insight about the use of different PDS's in certain types of projects?

Case studies are widely used to help evaluate complex systems and interactions such as strategies and management. Construction projects are rarely repeated in a way that allows for direct and specific comparisons between projects, particularly with respect to PDS. However, two school projects were identified during the data collection phase that allow for just that particular case study comparison based on PDS.

1.3 Background and Motivation for the Research

In the public sector of the construction industry in Oregon, owners have the opportunity to hire contractors with varying levels of project information prior to pricing, which is nearly unique among states in the US [55, 166]. Beginning in the mid 1980's, public agencies in Oregon started to use alternative construction contractor selection methods to hire firms on public projects. This process was authorized by law[1] as early as 1976, but little used prior to the mid to late 1980's, particularly in the building sector of the

[1] See Oregon Revised Statues: ORS 279.015 (as amended). The original statutory scheme was adopted in the 1975 legislature under House Bill #2339, set forth by then Attorney General Lee Johnson, and made effective January 1, 1976.

construction industry. The common contractor selection method used since the public bidding laws were enacted in the 1930's was by competitive lowest bid (commonly known as Design-Bid-Build, DBB or Lump Sum Bid, LSB method). However, by the early 1980's several public owners and construction contractors felt that the competitive lowest bid method was a principal contributor to an ever increasing litigious market sector, delays in completion, increasing insurance rates and bond costs and lower overall quality work.[2] As a remedy, first the Port of Portland[3] and next the Portland Development Commission[4] authorized negotiated procurements on their respective construction projects (called CM/GC jobs for Construction Manager / General Contractor method). In a little less than twenty years, from the early 1980's to the year 2002, public agencies in Oregon constructed more than five hundred public building projects; at least three hundred of those cost in excess of a $1 million each[5] in total representing nearly $5 billion in tax expenditures. At least 136[6] of those projects were negotiated procurements where contractor selection was based at least in part on prior performance of the firm on overall

[2] It is interesting to note that about this same time, in 1987 Dunlop [82]wrote that owners were going away from cost reimbursable contract forms and relying more on fixed price lump sum bid contracts in order to establish better cost certainty.

[3] The first known competitive negotiation selection for a construction contractor was the then K-Wing of terminal south at the Portland International Airport. It is not known why this project received an exemption from public bidding, no records of this project currently exist.

[4] The second known competitive negotiation selection for a construction contractor was for the Yamhill parking structure serving the Pioneer Place downtown development. The process was justified in that project because the PDC had bad experiences in the past with projects that did not finish on time and the parking structure had to finish prior to the opening of the mixed use development for holiday season. Increasing liquidated damages to cover the risk of developer lost profits was thought to be an uneconomical approach to ensuring the project opened on time.

[5] Our study focused on projects costing more than $5 million, some smaller projects were included if they met our project criteria for size and complexity.

[6] There are 136 known negotiated procurements in the database, and another 80 projects that the selection method is not known (whether lump sum bid or negotiated procurement). In addition, not included in the database are several CM/GC projects that are currently underway or recently completed, including high schools in Oregon City, Astoria, Salem and Beaverton totaling more than $100 MM.

project quality, schedule, and safety performance metrics. While there have been some attempts to analyze or audit specific negotiated projects, there have been no prior attempts to evaluate a large set of these projects and compare their collective performance against the more widely used competitive bid project delivery system (PDS) and evaluate the public policy in Oregon.

1.4 Project Delivery Systems (PDS)

The Construction Industry Institute (CII) defines a project delivery system (PDS) in [183] as:

> A project delivery system defines the relationships, roles and responsibilities of project team members and the sequence of activities required to provide a facility. Several systems have evolved over the years. Construction management at risk, design-build and design-bid-build are three principal project delivery systems used in the U.S. today.

More commonly, the PDS is considered the manner in which the owner hires a contractor for construction work, structures the contractual relationships and risks, and manages the project to completion. There are three principal PDS's: the traditional method Design-Bid-Build (DBB), a negotiated procurement method known as Construction Management/General Contractor (CM/GC) and Design-Build (DB).[7] The Oregon Public Contracting Coalition (PCC) [56][8] defines the different Project Delivery Systems commonly used in the public construction today as:

[7] DB projects can result from a negotiated or lump sum bid procurement method.
[8] See also [11, 102, 121, 139] for similar definitions.

CM/GC Construction Manager/General Contractor:

CM/GC augments the traditional scope of work of the general contractor with that of a construction manager under a single contract with the owner. At an early point in the design phase, the owner, using a competitive selection process, selects a contractor to provide construction management and general contracting services. By joining the project team during design, the CM/GC firm can collaborate with the architect/engineer (A/E) on the development of the design and preparation of the design documents. Once the design has progressed to an acceptable level, the CM/GC firm submits a guaranteed maximum price (GMP) for the project to the owner. After agreement on a GMP is reached, the GM/GC firm undertakes the construction of the facility. The CM/GC firm procures subcontracts with trade contractors using multiple bid packages to construct the project, and manages the construction process on behalf of the owner. General conditions work is typically self-performed by the CM/GC firm and, in some cases, the CM/GC firm may be allowed to self-perform portions of the trade work.

Design-Bid-Build

The design-bid-build process is the traditional approach to delivering public improvement projects. In this approach, the owner typically contracts with a design professional to design the project and develop construction plans and specifications. Construction documents are prepared and advertised for bids. Interested contractors review the construction documents and submit bids for the construction work. Selection of a contractor is determined based on a competitive bidding process. While the design professional usually will either employ an independent cost estimator or prepare its own cost estimates, the actual cost of the project is solely determined by the bidding contractors during the bidding process. Following receipt and review of the bids, and confirmation by the owner that sufficient funding exists, the contract is awarded to the lowest responsive and responsible bidder. The contractor then proceeds to construct the project according to the plans and specifications. During construction, the design professional observes the work to ensure that it conforms to the design plans and specifications.

Design-Build

Design-Build is an alternative contracting method used for delivery of both the design and construction services under one contract. This contract provides a single point of responsibility to the owner, namely the design-build firm. Many variations of this method exist, but all have "single point of responsibility" as a common element. Design-build can be undertaken when a performance specification is developed and the entire package of design and construction services is competitively bid. More commonly, the design-build firm is selected based on a combination of qualifications, technical approach, and price. Occasionally, the selection is made primarily on the basis of a design competition. By combining design and construction services under one contract, an opportunity exists to totally integrate the work of the contractor and the design consultant. This allows the selected firm to work with the owner during the design process to provide design, value engineering, constructability review, scheduling, estimating, and other related services. It also allows construction to start before the design is entirely complete. Though many variations exist, compensation for the design-build firm is typically based on a fixed price or, similar to the CM/GC process, a GMP.

For the purposes of this research, the term CM/GC will be used to describe both the PDS and also the party performing the work, such as the "CM/GC." Generally when an entity is referred to as "contractor" or "general contractor" the reference is to a DBB PDS, unless stated as the CM/GC contractor or as in the stakeholder analysis, where the context is clear.

The Design-Build or DB method will be discussed at length, but only in the context of the CII reports comparing the different PDS's found in the Appendix E. DB is not widely used in the Oregon public building sector, although it is beginning to be used in the highway building sector by the Oregon Department of Transportation. There were only two DB projects in the original Oregon database of projects; however, those projects, both parking garages, were discarded before the final analysis. In any case, since the CII goes to great length to include DB in its analyses of the different PDS's, it is discussed here also.

Chapter 3 details the data collection process that resulted in the Oregon database of projects. The Oregon database contains 407 projects; 510 were originally identified, but 103 of those projects were discarded as not meeting the project size or type requirements for this research. Of these 407 projects, 215 were actually used in the DEA and statistical analyses; we were unable to obtain enough information on the other 193 projects, many of which had been built nearly 20 years ago, and the final project records for the jobs had been either lost or destroyed. We were able to use all 407 projects in the Oregon database for some of the "project characteristics" that is included here. For example, we know what the original project bid or GMP cost of nearly all 407 projects was, therefore we can estimate with fairly high confidence the total dollar value of the Oregon database and the distribution between DBB and CM/GC projects.

1.5 Legal Construct

Public procurements are closely scrutinized for sound reasons, the public taxpayer must be assured that the money spent by public agencies for public projects is not wasted or spent for corrupt purposes. The federal government and most states, including Oregon, require competitive open public bidding as a means of assuring "fairness" in the awarding of public construction contracts [55]. Oregon Revised Statutes (ORS) makes this explicit in Chapter 279 stating:

> **"279.005 Policy of competition in public contracts.** (1) It is the policy of the State of Oregon to encourage public contracting competition that supports openness and impartiality to the maximum extent possible."
>
> **"279.015 Competitive bidding; exceptions; exemptions.** (1) Subject to the policies and provisions of ORS 279.005 and 279.007, all public contracts shall be based upon competitive bids or proposals ..."[9]

The law in Oregon allows for alternative forms of procuring construction services through the "exemption" clause in ORS 279.015(2) subject to a number of conditions that are discussed in detail in following chapters and Appendix C. More importantly, it is clear that the state favors open public bidding over any other form of construction procurement, which justifies the "challenger – defender" mechanism that is used in the data analysis of this research. That is, the defender is the "traditional" DBB method described above, and the CM/GC PDS form is the challenger. Under the state prescribed scheme of exemptions, the challenger "alternate" PDS must show that it is superior to the defender, or traditional DBB method. In Chapter 4 of this research, we use this legal construct to help set up and analyze the data, giving the defender every benefit of the doubt in terms of use of available information and performance of the work.

1.6 Validation

The sample of projects used in this research is not a "statistical sample" of all projects constructed during the research time frame; it is however, a large "convenient sample." We were able to identify 407 projects that generally met the research criteria for size and type of construction that were constructed in Oregon starting construction after

[9] The entire exemption statute, Chapter ORS 279.015 is included in Appendix C.

1986 and completed prior to 2002. It is unlikely that there were many more than these 407 projects constructed in Oregon during the research period that met the research criteria. Any projects that were missed are more than likely, projects that started and completed in the 1986 to 1994 time frame. This is because the DJC records going back nearly 20 years are not as good as those in the period since 1994 when they started keeping records on-line. Also, several public agencies, in particular Oregon Health & Science University (OHSU) and Multnomah County, archived their records, some of which either cannot be found or were destroyed.

To validate the data in the study, we compared the results of our data with that in the only other known similar studies; those performed by the CII and a report from the state of Washington. These comparisons are discussed in Section 4.1.2 and presented in Table 15.

The Oregon database presents the largest number of building projects studied to date, and it is clear from the comparisons that the differences between the Oregon database and the other study results are not significant. There is only one comparison where the difference exceeds 5%, which occurs in the comparison between schedule growth in the CII Benchmarking Study [51] and the Oregon database where all projects are combined. However, the standard error of the means of these populations is 4.7%, which is really quite large and means that the difference in the means (5.08%) is not significant.

Since the Oregon database results are consistent with the other studies on these metrics, we conclude that the data collected for this research is valid.

1.7 Results

1. Based on the statistical analysis of the output metrics cost and schedule control (in absence of inputs) the hypothesis that the CM/GC projects performance is superior to that of DBB projects is rejected. Group statistics indicate that there is no significant difference between the cost and schedule control outputs from CM/GC and DBB projects. Therefore we reject the hypothesis that CM/GC PDS results in projects that outperform DBB projects on cost and schedule control metrics.

2. Based on the DEA model and non-parametric statistical analysis, the null hypothesis that CM/GC do not outperform DBB projects with respect to overall efficiency (based on the DEA model) is rejected, and the alternate hypothesis, that CM/GC PDS results in projects with a higher mean technical efficiency scores than DBB projects cannot be rejected, and the difference is statistically significant.

3. Interaction analysis of the weights and slacks from the DEA model found no evidence of interaction between project type, performance and PDS. In addition, we found no evidence of clustering by PDS with respect to specific metrics, which indicates that there is no significantly different strategy employed by managers when using CM/GC or DBB PDS.

4. The stakeholder analysis indicates that the principal perceived benefits of choosing CM/GC over DBB is a reduction in project risk and reducing the adversarial relationship between the project management parties. The

perception of reduced risk is not supported by the data analysis, which shows no difference in cost or schedule control metrics between the two PDS's. Since project risk is generally the risk of going over budget or beyond the schedule, CM/GC does not reduce those project risks. The perception that the adversarial nature of the relationship between the owner and the CM/GC, as compared with the owner-DBB contractor relationship is reduced was not testable given the data we collected. Based on the earlier work by Goldblatt and Septelka [99] and this research, we observed that owners and CM/GC contractors that are involved in the work have a higher regard for the benefits of CM/GC PDS than do the design consultants and the subcontractors.

5. The case study comparison of two nearly identical schools built for the same owner, designed by the same architect, and constructed within one year of another, where one used DBB and the other CM/GC PDS, showed that the DBB project was built for significantly less total dollars and experienced lower cost growth. Furthermore the DBB project was less costly in virtually all cost categories. However, the CM/GC project was fast-tracked and the DBB project was performed under normal construction time constraints. The analysis adds more confidence to the recommendation that exemptions should be based primarily on schedule and not cost issues.

1.8 Contributions

The contributions of this research are as follows:

1. This research demonstrates that the current public policy used in Oregon to exempt public building projects from open competitive public bidding on the presumption of "substantial cost savings" to the public is not supported by the research. The research suggests that exemptions should focus primarily on schedule requirements. This research demonstrates CM/GC projects are more efficient than DBB projects when fast-tracking is required because the public pays no additional price in terms of cost and schedule control for starting the job with less than complete information.
2. This research raises questions about earlier research in the field that found CM/GC PDS superior to DBB on nearly all projects based on project outcomes.
3. The Oregon database compiled for this research includes 407 projects, 215 of which were used in the DEA model. This is the largest published database of public building construction projects in the literature.
4. This research fills several gaps in the construction management and DEA literature, including proposing the use of DEA as a benchmarking tool for construction project performance, which had not been done before.

1.9 Limitations

Most all research has limitations and the same is true here. The first and probably most obvious limitation is that the study is limited to building projects in Oregon. This means perhaps that the study cannot be generalized to the broader construction industry and to other states (although the state of Washington is discussed). Second, much of the data came from biased sources: owners and contractors, who support the continuation of the public policy for their own reasons. (However, half of the data was obtained directly from project files kept by owners.) Third, the Expert Panel members contributed much of the data used in this study. This was done on purpose because it was felt that, particularly construction industry members, would be more willing to participate in the research if they had a hand in helping to develop the metrics. Furthermore, the elicitation and derivation of the metrics process would serve as part "study education" that would streamline the data collection process. Finally, the projects are not a random statistical sample of the population of all projects, instead they represent all the projects that we could obtain data on. The Oregon database represents a convenient sample of the building construction projects in Oregon during the study period, but it is a rather large convenient sample. It is possible that the 193 projects in the Oregon database that were not used in the model could affect the outcome of the analysis. However, it should be noted that the group statistics for the Oregon database were substantially similar to those found in prior studies.

2 Literature Review

This chapter is an examination of the previously published literature that forms the basis for this investigation. The chapter includes prior research in construction, bidding selections, negotiated procurements, DEA and includes references to prior studies in the area, which are found in the Appendix E.

2.1 Overview

There exists a great body of literature in the areas of vendor selection, multi-criteria decision making, bidding theory, construction contracting and Data Envelopment Analysis (DEA). Here, the focus of the discussion is on the application of different techniques to the problem of public-sector construction contractor selection and post project evaluation. Until 1976 the public-sector in Oregon, like much of the country, had only one method for choosing a construction contractor on a public building project: lowest lump sum bid (LSB method) [37, 55, 79, 166]. Therefore, the discussion here will begin with a review of the literature on the construction industry and in particular auctions and competitive bidding theory as it applies to construction contractor selection. Some details such as an example of bidder mark-up calculations are presented in the Appendix D.

In recent years, in Oregon, the public-sector has experimented with "alternative contracting methods" such as competitive negotiation as a method of construction vendor selection as documented by Douthwaite [79] and substantially similar to the process described by Skitmore and Marsden [193]. This method requires the application of multi-criteria techniques or scoring models.

A great effort has been made to obtain all of the prior reports of similar work preformed by other researchers as well as project evaluation reports and audits by state and local auditors for specific projects. The Construction Industry Institute (CII) at the University of Texas at Austin has been the most active single institution in performing these types of comparisons. A brief critical review of the CII work is found in this chapter with a more in-depth presentation found in the Appendix E. A comparison of the data analysis and results from the CII studies and this work is found in Chapter 4.

Finally, project evaluation or "Benchmarking" and the application of Data Envelopment Analysis (DEA) to this problem are covered. DEA is a widely used tool for benchmarking and efficiency analysis, specifically in public sector applications. However, to date this tool has not been applied to the evaluation of construction contractor selections.

In his book, *History of Government Contracting,* Nagle [154] states:

> "Much of this country's contracting history has been spent trying to find the best combination of three factors: the right contracting apparatus, the right government-contractor relationship, and the correct contract form itself."

This study touches on all three of factors. In this chapter of the study, a review of the literature concerning the different forms and contracting methods is reviewed.

2.2 Taxonomy of Literature and Relevant Gaps

Project benchmarking, project performance, management and vendor selections are among the overlapping topics in the DEA and construction industry literature. However, while these are common themes in the literature, there is little crossover in the two disciplines (meaning that DEA has rarely used to analyze construction industry performance). This overlapping of topics is graphically depicted in Figure 2 below. Five major gaps have been identified, labeled "A" through "E." This is not a complete list of the literature in either field, merely some of the main points discussed here (in fact both the DEA construction literature fields are quite voluminous with entire journals dedicated to construction and project management, as well as several journals that focus on DEA and the applications of the methodology).

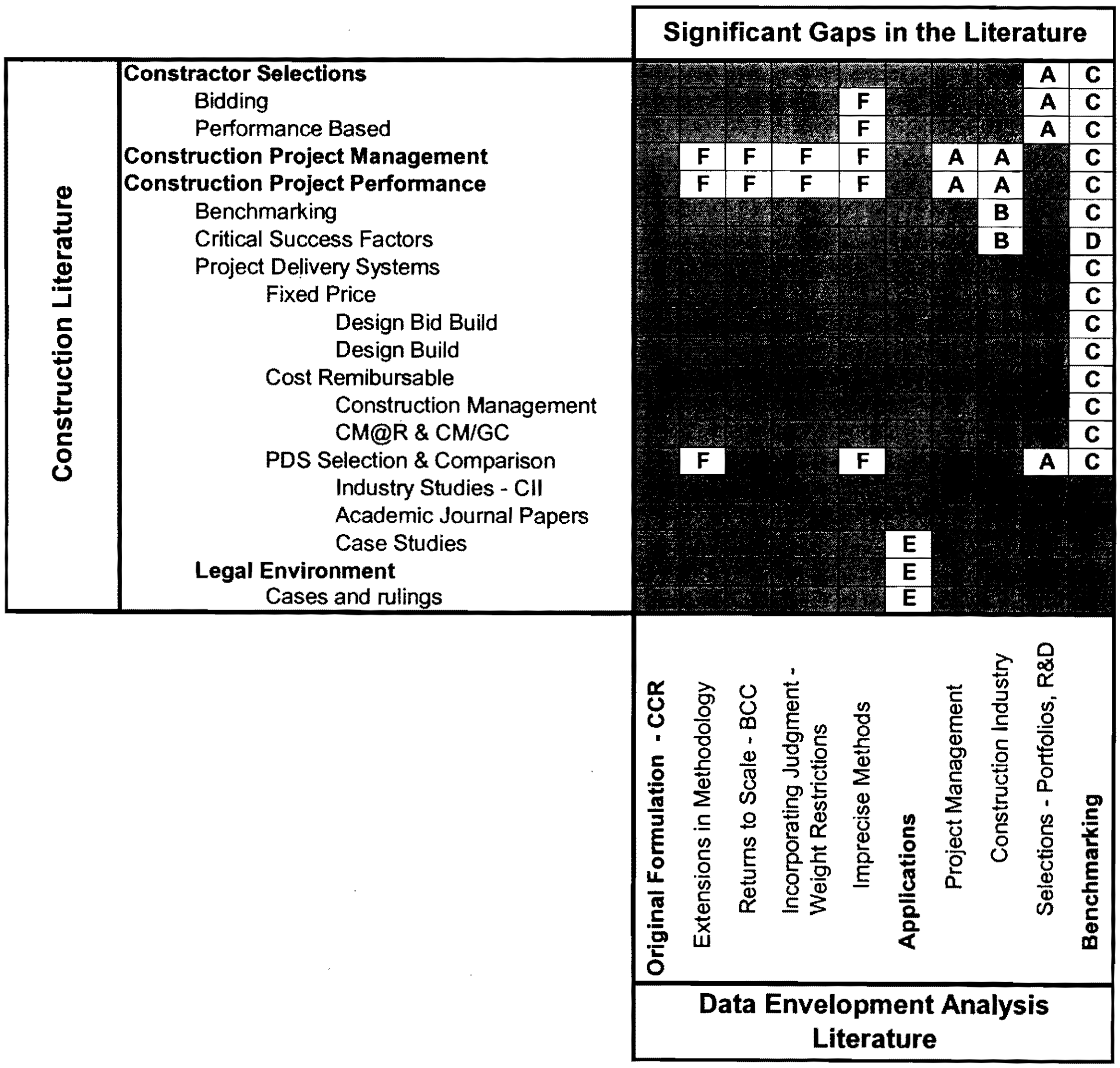

Figure 2: Relevant Literature Gap Analysis

The gaps identified here are termed "relevant" gaps; there are numerous gaps in the DEA and construction literature intersection that are of no consequence or concern of this research.

The gaps in the literature that are noted in Figure 2 are as follows:

A. While DEA has been used as a tool to help make selections, such as R&D project and investment selections among other things, its application to construction project selection has been limited to one unpublished report on roadway construction and maintenance projects.[10] While Cook *et al.* [60] (also found in [41]) evaluated highway maintenance crews using DEA, there is no application in the DEA literature that purports to evaluate construction project performance or selection of construction contractors or construction project delivery systems.

B. There are many papers in the construction literature that discuss critical success factors and benchmarking metrics, and there are literally hundreds of DEA applications using input and output metrics. However, there are no papers in the DEA literature that actually give researchers guidance on how to derive metrics for DEA models. The application from [60] uses a formula that the authors derived, but no documentation is given why they used the metrics they used, except the fact that the data was available.

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[10] This project was presented at the Fall 2000 INFORMS in San Antonio, Texas, by Dr. Timothy R. Anderson and this author.

C. DEA is a widely used benchmarking tool; however, there are no papers in the DEA literature on benchmarking in the construction industry generally, construction project performance or the wider general uses of bidding and negotiated procurements. Furthermore, only one previous study by Sanvido and Konchar [183] compares project performance based on PDS.

D. There are no benchmarking studies in the DEA literature on construction project delivery systems.

E. There are no case studies in the literature that compare two nearly identical projects that used different project delivery systems in order to evaluate the efficiency of the delivery systems.

F. The DEA literature includes many methods to deal with scale differences and imprecise input and output data. However, currently there is no guidance given in the literature of how to deal with extremely non-linear and missing data that resides on one side of the DEA model. Nor has there been any pervious evaluation of the proper DEA formulation to evaluate the performance of construction projects or inelastic information has been made.

In addition to these gaps, there is very little in the construction literature that directly compares project delivery systems by outcomes. That work is basically limited to a group of studies performed by the CII, Design-Build Research Team.[11]

[11] Also, reportedly funded by the Design-Build Institute.

2.3 Construction Industry

The construction industry is often referred to as the largest single economic sector other than government, and consequently the body of literature on the construction industry and construction bidding is quite large. It is generally found in the professional journals of the American Society of Civil Engineers and others. However, some of the earliest analysis of bidding is found in the areas of operations research, management science, economics and engineering management.

Carty [37], Clough and Sears [54] and Halpin [102] provide very good overviews of the construction industry: its history and development, role in society as well as describing the major contracting methods evaluated in this study. Nagle [154] provides a history of Federal Government contracting, which focuses on arms procurement and mail contracts. A history of the Oregon construction industry, as it relates to the carpenter labor union, is presented by Wollner [222]. The construction industry legal structure is reviewed in the authoritative references prepared by Cibinic and Nash[12] [49] and Bednar, Braude and Cibinic [22]. Construction industry bidding law is documented by Cushman and Doyle [70] and updated by Rhodes [166]. In addition there are several texts on Construction Law, including bidding, both nationally [32, 71] and pertaining specifically to Oregon [31].

Carty [37] describes the different types of construction contracts as: lump sum, unit price, guaranteed maximum price (GMP), construction management (CM) and design

[12] Professors Nash and Cibinc have written several authoritative works on contracting in the Federal Government system. They are both with George Washington University Law School in Washington D.C., where the Federal Circuit Court for the Federal Circuit, The Federal Court of Claims, and all of the Boards of Contract Appeals are located. The Public Contract Law Journal is also published at the George Washington University Law School for the same reasons.

construct (also known as "design-build"). Gordon [101] and others [56] provide guidance on selecting contracting methods; however, in the public-sector in Oregon, only three of these methods are currently being used on a regular basis: lump sum, unit price and negotiated GMP[13] [79, 80]. Myers [152] evaluates design-build approaches elsewhere in country, but Design-Build has not been used extensively in Oregon. Also, it should be noted that unit price contracts are typically awarded on a lump sum basis (equal to the unit price multiplied by the estimated number of units) and are generally limited to transportation and utility construction contracts (such as: roads, sewers, waterlines and so forth). Here, the discussion is limited to "building" contracts. Building contracts differ from transportation and utility contracts in that they generally require the contractor to provide many specific items of work (often times several hundred) for one complete bid price. Transportation and utility contracts typically require fewer specific items to be provided by the contractor, but they require many more "units" of each item. In addition, the exact number of "units" of any specific item the contractor is required to furnish and install is typically defined to plus or minus a certain percentage of an estimated amount.[14] This requires the bidder to bid many individual unit prices and sum the product of the unit prices and estimated number of units to determine the total bid. There is a great deal of complexity associated with both lump sum and unit price bidding. The fact that this study

[13] Design-Build, either negotiated DB or bid DB are not frequently used in Oregon, but have been used on at least two public projects, a parking garage and a maintenance facility, both for Tri-Met, a local transportation district, those projects, together with some DB highway projects have been executed since [80] was published.

[14] Contractors are generally required to prepare a bid on the estimated quantity, knowing that the actual pay quantity (unit price * number of units) may vary by some amount (or percentage) prescribed in the contract. Unit price bidding has the effect of shifting the risk for quantity assessment from the contractor to the owner, meaning that the owner takes the risk of additional quantities of work actually installed.

focuses on lump sum building contract types is not to imply that they are more or less complex than unit price bids.

2.4 Construction Industry and Bidding

2.4.1 Bidding and Auction Theory

Construction contractors have traditionally been selected on the basis of the lowest responsible competitive bid [101, 149]. Bidding theory is a rich source of published research dating back to the 1950's. The majority of this work was published in the 1970's and 1980's; however, a steady stream of auction and bidding research continues to this day (for example: [66, 118, 173, 206] were all published in the past three years). There have been several bibliographies and surveys of competitive bidding published since this area of interest within the economics and operations research communities was developed; some of the more complete surveys include Wilson [220], McAfee and McMillan [146], Milgrom [147], Milgrom and Weber [148], Engelbrecht-Wiggans [87], Rothkopf [173] and a recent book by Kagel and Levin [118]. More compact reviews can be found in Rothkopf and Harstad [174]. Though dated now, Stark and Rothkopf [197] and Stark [196] have published extensive bibliographies in the field.

In the literature, competitive bidding theory is synonymous with, or considered a subset of, auction theory. An auction is an economic institution designed for the exchange of goods or services, where the exact selling or purchase price of the good or service is unknown prior to the auction [173]. The price of the exchange is established by bidding among parties wishing to either purchase or sell the good or service. Types of auctions are distinguished by the rules determined by the auctioneer (who could be either a third party or the principal buyer or seller). The various auction types in general use can be classified by following characteristics: highest or lowest bid, first or second price, private or common value, in combination with open (often oral) or closed (typically sealed) bidding.[15] The principal concern here is with the most common form of bidding used in the construction industry, lowest bid, first price, common value, closed bidding auctions [174, 224].

2.4.2 Friedman's Basic Model

While auctions have been around for centuries, a theory of auctions and competitive bidding was only established in the last fifty years. Most researchers[16] credit Lawrence Friedman [91] for first analyzing the general bidding problem and formulating an expected value model for optimal bidding strategy. At about the same time as Friedman's work, Percus and Quinto [161] applied linear programming to the problem of "Competitive Bond Bidding," specifically, government bonded debt. However, most subsequent researchers use Friedman's model as the point of departure for future work. Friedman derived the expected value model:

$$E(x) = P(x) * (x - C') \tag{2.1}$$

[15] By closed here we mean the bid itself is not disclosed prior to bid opening, not that the bidding itself is closed to a certain set of bidders, which may or may not be the case.
[16] One exception is Ibbs, [112] who cites a 1944 Columbia University thesis analysis of Competitive Bidding for Corporate Securities.

Where E(x) is the expected value of winning, P(x) is the probability of a bid "x" will be the winning bid and "C" is the estimated cost corrected for bias. Friedman's original work has been extended in many ways by many researchers. Hanssmann and Rivett [105] were among the first, extending Friedman's model to estimating the probability of winning and devising a method for analyzing simultaneous bids on several objects sought. Simmons [192], Wilson [219, 221], and Rothkopf [171, 172] all followed, with Crowley [66] continuing the discussion regarding the different probabilities derived in the Friedman and Gates models.

2.4.3 Bidder's Mark-up or Fee

Mark-up or contractors' fee is an important part of any discussion of construction contract bidding as discussed in Curtis and Maines [68, 69] and Fuerst [92, 93]. The mark-up is often considered to be the principal strategic component of the construction bid, and a considerable amount of work has been done to calculate the theoretical optimum mark-up in order to maximize the expected profit of any given bid [21, 35, 91, 132, 145, 153, 159, 181, 201, 218]. These works consider several factors such as number of opposing bidders and variance in the value of the good sought. With respect to construction contract bidding, these sometimes simple analyses significantly understate the complexity in determining construction bids as demonstrated by Akinci and Fischer [5]. Beyond these theoretical developments, the determination of fee or expected profit from a project is obviously a principal concern to both the prospective contractors and those who pay the bill, since contractors must make enough to stay in business and owners and the general public don't want to pay too much in the form of exorbitant profits. Contractors generally consider risk, market and return on investment when calculating mark-up and fee; an example of construction company mark-up and fee calculation is presented in Appendix D.

2.4.4 Auction Classifications

Auctions are often classified by type, otherwise known as design or format by which the selling takes place. There are basically two types of auctions that are executed in a number of different formats. These are Common Value and Private Value Auctions or bidding. Private Value Auctions occur when the bidders have a different private value for item sought, such as the value of artwork. Common Value Auctions occur when the value of the item, once won, is common to all of the bidders. These models include bidding on items for resale (such as the Dutch flower auctions), and as in the case of this research, construction project revenues.[17] Auctions can be executed in the open, oral form, or as in construction bidding, typically the closed, sealed bid form. The only auction type and form of interest here are closed sealed bid common value auctions as discussed by Kagel and Levin [118].

"Construction contract bidding is usually treated as a common value auction," according to Kagel [118]; this is because, theoretically, all of the bidders will experience the same cost basis to perform on the contract, but each bidder has a different estimate of what those costs are. The most optimistic or lowest estimator of those costs (or perhaps the most aggressive bidder) will submit the lowest price bid. Since the cost of production

[17] In short, that is what construction project bidding is all about, the contractor provides a bid for the revenues required to pay for the services purchased, often through subcontractors or his own labor and materials. These services are generally considered to cost all bidders the same amount, so the contractor that provides the lowest bid is in essence bidding the least expected difference between revenue and cost or bid amount and cost, which is the same thing.

remains relatively constant[18], regardless of the bid price, the possibility for negative profits exists. This is generally referred to as the "winner's curse."

2.4.5 The Winner's Curse

To paraphrase Landsburg [131] from his book *The Armchair Economist* on the subject of winners curse in a chapter entitled, "Cursed Winners and Glum Losers:"

> "Economic theory predicts that you're probably not liking this [dissertation] as much as you thought you would [when you agreed to read it]."

Although he was being somewhat whimsical in his introduction to the subject, he does summarize much of the important characteristics of the winner's curse phenomenon, particularly as it applies to the construction industry. The idea was first brought into the literature by Capen, Clapp and Campbell [36] in their review of high risk outer continental shelf oil and gas lease auctions. They conclude that, "[i]n competitive bidding, the winner tends to be the player who most over estimates true tract value." They go on to show that the "law of averages" simply doesn't apply in common value competitive bidding, because with a sufficient number of bidders, any bidder only wins if he or she over-values the item sought and in every bidding situation, some bidder will over-value the item. Which implies that competitive bidding must, over the long run, result in substantial financial

[18] This is particularly true in public construction where prevailing wages for workers are set by the state in Oregon. However, there may be slight differences in cost of production for example if one of the bidders has developed a better, cheaper way to perform the work.

losses in those industries where it is practiced. However, Wood [224] gives an alternate interpretation:

> "The winner's curse is perhaps better defined not by the existence of negative average profits to the winning bidder, but rather Milgrom's necessary reassessment of value after winning, or by the observation that optimal bidding behavior in affiliated value situations generally calls for less aggressive bidding as the number of opponents or the bidder's own estimating uncertainty increases."

Another interpretation common in the construction industry is to attribute the winning low bid to a "mistake" and deem the winner the bidder who made the biggest mistake.

Winner's curse has spawned significant research in recent years, first in analyzing its existence [36] and predicting its magnitude in order to calculate an optimal mark-up to cover the anticipated costs or loss in revenue [83, 129, 192]. Harstad and Rothkopf [107] and Simmons [192] give methods to guard against winner's curse by allowing withdrawable bids and better estimating techniques. Cox [65] disputes the very existence of a winner's curse, or states that "if a winner's curse is a behavioral reality, then bidders are not generally using ex ante optimal strategies." Thiel [204] studied highway construction bidding in 33 states and determined that the winner's curse is not a "significant problem in the highway construction industry." Although Thiel "believes that the winner's curse is at most a slight problem in [the highway construction] industry" he states that, "the data [may allow for] other interpretations." Thiel's conclusions are admittedly somewhat suspect, in that he incorporated the owner's estimate of the costs in his determination of the magnitude of the curse, but that is a common technique also used in an Oregon highway construction audit by Lattimer [135].

Kagel and Levin [117] found that "in auctions involving a limited number of bidders (3-4), average profits are consistently positive and closer to the Nash equilibrium bidding outcome than the winner's curse hypothesis." However, with a larger average number of bidders (5-6) they find a "reemergence of the winner's curse, with bankruptcies and negative profits." They supported these findings in later studies [119, 138].

Winner's curse is of particular concern in the public sector of the construction industry where most owners continue to use DBB as their primary PDS. Kagel [118] and others have studied common value auctions and the winner's curse in the construction industry and concluded that while experienced construction bidders are subject to winner's curse affects, the construction market attempts to correct for the curse by employing three strategies:[19] withdrawal of a low bid due to error, subcontractor buyout, and by overpricing change orders. Kagel also points out that there is a significant amount of "private information" in the bidding environment that is not accounted for by the plans and specifications, some of which can be characterized as "experience" of the bidders and reliance on "rules-of-thumb" in bidding.

In Kagel's brief review of the construction industry for his research, he concludes that contractors rely primarily on the plans and specifications as the primary information as

[19] Although, not necessarily by these names.

a basis for their bid. In fact, that proposition is solidly embedded in both federal and Oregon contract law.[20]

2.4.6 Mistake

In any discussion of construction bidding, considering the complexity of the market, there is some an appreciable probability of a mistake in the bid. A mistake is not an error in judgment, such as choosing the wrong labor production rate or the wrong equipment to do the job [71]. A mistake is a clear objective omission. It is a generally accepted rule that a contractor may be allowed to rescind a bid if there is a mathematical error or omission that is "material" [29]. (Harstad and Rothkopf touch on bid rescission in light of a mistake as "winner's curse insurance" [107], although that was not the main point of their paper.) There is less consistency on whether or not a rescinded bid will automatically result in forfeiture of any bid security (a bond or cash). Different government agencies have developed different policies in this regard, although the legal standard appears to be more certain [70, 71, 166].

While bid withdrawal may protect a bidder from a certain class of problems, specifically leaving out some major item of work or making a substantial mathematical error, it does not protect the contractor from similar but smaller mistakes that go undetected until the project is well underway. Another class of mistakes involves the subcontractors chosen for the project. At bid time, the estimators choose the low subcontractor bids to cover all sections of work specified in the contract documents. However, subcontractor

[20] See In United States v. Spearin, 248 U.S. 132, 39 S.Ct. 59, 63 L. Ed. 166 (1918), and Oregon, A.H. Barbour & Sons, Inc. v. State Highway Commission, 248 Or. 247, 433 P.2d 847 (1967); General Construction Company v. Oregon State Fish Commission, 26 Or. App. 577, 554 P2d 185 (1976).

bids often include exclusions of one item or another within a specification section bid, and this can cause "holes" (items of work that get left out) and in some cases a "double-up" (where two subcontractor's include a specified item of work in their price). Holes in the bid reduce the general contractor bidder's profit, while the double-up serves to increase it. These types of problems (and the probability of mistake generally) are heightened in the DBB method because general contractors receive the majority of subcontractor bids in the final hours (sometimes final minutes) before the total bid from the general contractor is due by the owner. Bids that are received late, after the prescribed "bid time," are rejected as a matter of law on public projects in Oregon, so there is a natural rush to finalize the number before bid time, which leads to a higher likelihood of mistake. In the CM/GC PDS, the CM/GC has the opportunity to take as much time as needed to both review the bids of subcontractors and perhaps more importantly, define the scope of work for the subcontractors, thereby reducing the probability of "holes" in the bid.

2.5 Non-Bid Negotiated Contractor Selection Methods

From 1935 until 1975, public agencies in the State of Oregon had little choice but use a lowest, lump-sum bid selection process. In 1975, the State Legislature passed an exemption to the public bidding law for "certain projects" or "certain types of projects." The use of bid exemptions to select construction contractors exploded in the period from 1985 to 1996, accounting for more than $1.6 billion in public construction spending on more than seventy projects during that period. By 2002, when this study concluded its data collection efforts, more than $2.9 billion in public construction spending on more than 136 projects had been exempted from the public bidding requirements. However, there is very little in the construction project management or construction industry literature regarding non-bid negotiated procurements with the exception of guides for choosing method and how to use them effectively by the CII, OSU's Construction Engineering Management Program and others [56, 76, 101], and the CII Design-Build Research Team work authored by Sanvido and Koncher [127, 183] that provides the only prior analysis of PDS performance.

The actual selection process used under the exemptions clause of the public bidding law has evolved from "no direction" at all in the early years to requiring the identification of selection criteria and weighting (or relative priority). Additionally, the 1997 legislature placed further restrictions on the use of non-bid methods by requiring public agencies to hold public hearings to make public findings and provide a follow-up report of the actual project outcomes with respect to the original findings report. At the same time, however, the legislature exempted the Oregon University System and the Oregon Health and Science University from all public bidding requirements under Chapter 279.

2.6 ORS Chapter 279 Public Bidding and Exclusions

Jervis and Levin [114] note that "in this country, competitive bidding is required by law on virtually all construction contracts that involve public funds. The competitive bidding requirement serves two primary purposes: conserving tax dollars and promoting fairness." The underlying assumption is "that the lowest possible price will be received if the contract is awarded on the basis of open competition" involving a sufficient number of competitors. Secondly, as "strong as the need to conserve tax dollars is, the promotion of fairness is an even more imperative purpose of the competitive bidding system, there is broad consensus in our society that public contracts should be awarded on the basis of the contractor's ability and willingness to offer the low price. Graft and local favoritism must not play a role in the selection of contractors." Such concepts have given rise to the "rigid, formalistic structure of competitive bidding ...[which is] designed to avoid not only impropriety but even the appearance of possible impropriety. In order to maintain public confidence ... [and] the integrity of the competitive bidding system" [114].

2.6.1 ORS Chapter 279 and Public Bidding

Oregon Revised Statute (ORS) Chapter 279 is the State public bidding law. It came into being during the 1935 legislative session and remained virtually without amendment for nearly 40 years until 1975, when the section 279.015 was added by House Bill #2339, which took effect January 1, 1976.[21] The original law required nearly all spending for public goods and services, not limited to construction projects, to be put out for competitive sealed bids.

The sealed bidding process maintains objectivity and the integrity of public spending and is preferred by statute; however, mandated sealed bidding lacks flexibility. This lack of flexibility is particularly acute in times of emergency and economic isolation.[22] The fundamental requirement of sealed bidding is that the Owner must be capable of specifying minimum performance for the public project. In an emergency situation, this is

[21] It should be noted that another major rewrite of ORS Chapter 279 began in 2002 in order to address the differences in procurement for "supplies," and that required of "services."

[22]By "economic isolation" I am referring to a condition where an Owner has few, if any contractors to choose from to do the work. In these situations, it is highly likely that the Owner will pay more than the normal value or "goring rate" for the contractor's work.

clearly impossible. Arguably, it may also be impossible to specify minimum performance in extremely complex projects and certainly those with significant design-build or fast-track elements.

2.6.2 ORS Chapter 279 and Non-Bid Procurement

In 1975, the state legislature took action to rectify Chapter 279's lack of flexibility and adopted an exemption clause by authorizing HB #2339 and making it a subsection of the public bidding law: ORS 279.015. This clause sets forth as a condition for granting any exemption from public bidding upon a finding that, "[i]t is unlikely that such exemption will encourage favoritism in the awarding of public contracts or substantially diminish competition for such contracts" and results in "substantial cost savings" to the public contracting agency and, by extension, the taxpayers.

The use of bid exemptions was minimal and primarily limited to emergency situations and continuation of original supplier and maintenance contracts (such as elevators and mechanical controls) and on one occasion to extend a project bid deadline.[23] By the mid-1980's public agencies had begun using the bid exemption provision to exempt certain new major public construction contracts from competitive lump sum bidding. The use spread rapidly, and by 1996, public agencies had used this provision to exempt more than forty new major construction projects totaling nearly $1.6 billion in public spending. By 2002 the total exceeded $2.9 billion, as shown in Table 1.

[23] See Oregon Attorney General Opinion Requests: OP-6063, 6234, 5873, 8161 and 7992

Project Type	CM/GC	DBB
Housing	15,504,677.72	22,396,317.47
Library	81,481,218.05	108,105,178.31
Major Remodel of Existing Bldg	174,304,811.42	62,863,526.83
Mixed New and Remodel	596,077,946.22	118,040,458.01
New Corrections, Jail or Prison	717,594,701.20	42,720,921.68
New Hospital or Medical Building	94,143,069.84	92,002,502.14
New Industrial	146,928,199.73	39,284,451.18
New Institutional	278,374,899.29	285,382,671.99
New Office Building	163,418,208.19	29,972,630.20
New School Building	404,738,846.46	778,249,827.19
Other	115,718,781.36	4,229,853.82
Parking	26,328,393.32	62,106,850.50
Sports Facilities	103,882,821.46	21,318,840.07
Grand Total	**2,918,496,574.27**	**1,666,674,029.39**

Table 1: Dollar Volume of Projects in the Oregon Database in 2002 dollars adjusted using the *ENR* index for Building Construction

While several researchers have commented that the DBB method increases the adversarial relationship between the owner and contractor [45, 46, 94, 101], the only issue considered in exempting a project from competitive bidding is cost, specifically that the exemption will result in substantial cost savings to the public. The relevant sections of Chapter 279 are as follows:

> **279.015 Competitive bidding; exceptions; exemptions.** (1) Subject to the policies and provisions of ORS 279.005 and 279.007, all public contracts shall be based upon competitive bids or proposals except:
>
> ... A public contract exempt under subsection (2) of this section.
>
> (2) Subject to subsection (6)(b) of this section, the Director of the Oregon Department of Administrative Services or a local contract review board may exempt certain public contracts or classes of public contracts from the competitive bidding requirements of subsection (1) of this section upon approval of the following findings submitted by the public contracting agency seeking the exemption:

> (a) It is unlikely that such exemption will encourage favoritism in the awarding of public contracts or substantially diminish competition for public contracts; and
>
> (b) The awarding of public contracts pursuant to the exemption will result in substantial cost savings to the public contracting agency. In making such finding, the director or board may consider the type, cost, amount of the contract, number of persons available to bid and such other factors as may be deemed appropriate.
>
> (The entire statute is presented in Appendix C.)

2.6.3 Litigation Concerning ORS 279.015

A search of West Group publications,[24] using the Lexis® computerized search engine in September 2003, netted surprisingly few (only eleven in fact) documents related to ORS 279.015 bidding exemptions. Of these, four (4) are Attorney General Opinions (Numbers 7476, 7546, 7648, and 7992) on specific questions related to the bidding requirements asked by public agencies. [25]Other questions presented to the Attorney General involved the impact of ORS Chapter 279 provisions on the sale of surplus property and Federal Energy Policy and Conservation Act; none of these directly dealt with the construction sector, but show the broad application of the public bidding law and the policy intent of the state as it relates to purchasing through the competitive bid process.

Three of the court cases that referenced ORS 279.015 were not related to public construction contracts. Double Eagle Golf, Inc. v. the City of Portland involves the award concession contract to operate public golf courses in Portland. Photo-Art Commercial

[24] West Group is the official publisher of legal court documents and recorded cases in Oregon.
[25] For example, the Oregon Military Departments asked the Attorney General if "food concession contracts must be obtained through the Department of General Services?" (The answer was: "yes.")

Studios, Inc. v. E.S. Hunter, Deputy State Highway Engineer, involved a contract between the State Department of Transportation (ODOT), and a film producer and Dale v. Meyers and Sizemore v. Meyers, was a ballot measure dispute, involving contracting out government services to private entities.

In the four construction cases in which the court was required to make a ruling regarding ORS 279.015, two, Taggart, Inc., v. Douglas County and Platt Electric v. JC Northwest and Polk County Housing Authority, do not present any issues related specifically to the exemption clause, but rather dealt with bonding issues.

The two construction cases that required the court to rule on the exemption provision of Chapter 279.015, were: Morse Bros. Prestress v. City of Lake Oswego [1] and ABC v. Tri-Met [2]. In Morse Bros., the court held that the defendant, City of Lake Oswego Board:

> made findings and recited them in the preamble to the resolution adopting the regulations. The findings are phrased in the words of the statute and, although general in nature, are sufficient to support the regulations.

This means that the "findings" requirement in the statute does not need to be supported by anything other than a recitation of the wording in the statute – a finding that other courts have subsequently relied on.

The Associated Builders and Contractors (ABC), an association of nonunion construction contractors, brought suit against the Tri-County Metropolitan Transportation District (Tri-Met) and the Tri-Met Contract Review Board to ask the court to set aside the exemption of certain contracts for a light rail extension to the Portland Airport. Tri-Met had exempted the contract from public bidding in part to comply with the terms of a development agreement between Tri-Met and Bechtel, the developer builder. In short, Bechtel was awarded the contract to build the light rail line in absence of public bidding, pursuant to the specified findings under ORS 279.015. Bechtel in turn required all contractors working on the light rail project to be "union" or to sign project labor agreements (PLA) with the union. ABC and its non-union members objected to the PLA requirement on a public project and challenged the exemption under the statute. The court held that:

> (1) [The] trade association had standing to challenge board's exemption decision;
>
> (2) [The] district was not required to use alternative contracting practices in exempting contract form competitive bidding;
>
> (3) [The] board was not required to consider [the] effect that awarding contract would have had on competition among subcontractors for work on the light-rail project; and
>
> (4) [The] board's findings were sufficient as to form and were supported by substantial evidence.

In summary the court ruled, among other things, that the requirement in the statute to make a finding that the exemption would not "encourage favoritism" or "substantially diminish competition" was relevant only to the contracting parties that have privity: the agency and their contractor, and does not extend down to the subcontractors. ABC v. Tri-Met is the most significant challenge to the exemption clause to date, and in that case, the court sided solidly with the public agency's right to exempt construction contracts from public bidding, following the statutory "findings" without giving any consideration to the non-contracting parties, the subcontractors. This is important because many agencies that have exempted contracts from bidding use as a basis for their finding that "the exemption will not diminish competition" or "encourage favoritism," the fact that they will bid out the subcontract portions of work. This ruling renders those considerations moot.

2.7 Alternative Selection Models Considered

Most of the CM/GC selections to date have used some form of scoring model where points were awarded to proposers based on their response to the established criteria [80].

Several alternative scoring models are discussed in the management science literature [53, 198]. The selection of an appropriate model for the particular application depends primarily on the level of project complexity and rigor of the decision required. One of the more complex and rigorous applications is the Analytic Hierarchy Process using pair-wise comparisons [125, 178-180], which in fact has been used on a at least three occasions to select construction contractors. Less complex models include: Simple Rank Ordering, Simple and Probabilistic Scoring Models and Queue Sorting. DEA has been suggested as a possible multi-criteria decision model [81]; however, to date that application has not been made in the construction industry and is not considered here. An advanced analysis of multi-criteria methods is given by [208]; however, here again, the complexity and rigor of the decision required heretofore has not required such advanced techniques.

2.7.1 CM/GC Selections, As Practiced:

A survey of 19 CM/GC projects shows that public managers generally use simple ordinal scoring models to evaluate proposals for construction contractor selection. The study found that the selection models used were substantially similar to one another, with the majority of evaluations considering similar common selection criteria [10]. For the 19 projects surveyed, a total of 29 different selection criteria were used. The following Table lists various criteria found common to several projects:

Criteria:	% Projects Used	Ave. Weight %
Qualifications of Key Personnel	95	19.2
Proposed Work Plan	79	14.9
Company Experience	74	19
CM/GC Fee	63	12.9
Ability to Perform	47	24.3
Value Engineering Capabilities	42	9.5

Table 2: CM/GC selection criteria used

While most projects used similar selection criteria, the study was unable to find a significant correlation between project type and criteria used for contractor selection, meaning that the selections appeared not to reflect the particular challenges of the specific project, but were more generally looking for a "good" contractor. One of the problems with this approach is that it sets fixed weights in the determination of a "good" contractor and how a project should be managed. (For instance, if a specific weight is given to safety, the model is prescribing a certain amount of management attention be given to safety as opposed to quality of work or reducing costs.)

For some projects the actual judges scoring sheets were obtained, comparing specific contractors. An analysis of the scoring showed that various criteria scores were highly correlated. A high score on "key personnel," for instance, was found to predict a high score on "ability to perform". Likewise, a high score on "experience" predicted a high score on "proposed work plan". In addition, and more disturbingly, some judges scoring sheets appeared to reflect biases for or against particular contractors. This was evidenced in one instance where a judge gave one contractor extremely low scores (on a zero to five scale) for all criteria under consideration while every other judge rated the specific contractor the best of the competition. This in effect vetoed the contractor from the competition.

2.7.2 ORS 279.103 Reports and Secretary of State Audits

In 1997 the Oregon legislature enacted ORS 279.103, which reads as follows:

> **279.103 Evaluation of certain public improvement projects not contracted by competitive bidding.** (1) Upon completion of and final payment for any public improvement contract in excess of $100,000 for which the public agency did not use the competitive bidding process, the public agency shall prepare and deliver to the Director of the Oregon Department of Administrative Services or the local contract review board an evaluation of the public improvement project.
>
> (2) The evaluation shall include but not be limited to the following matters:
>
> (a) The actual project cost as compared with original project estimates.
>
> (b) The amount of any guaranteed maximum price.
>
> (c) The number of project change orders issued by the public agency.
>
> (d) A narrative description of successes and failures during the design, engineering and construction of the project.
>
> (e) An objective assessment of the use of the alternative contracting process as compared to the findings required by ORS 279.015.
>
> (3) Evaluations required by this section shall be made available for public inspection.
>
> (4) The evaluations required by this section must be completed within 30 days of the date that the public agency accepts the public improvement project.

An evaluation of all known evaluation reports is included in Appendix F. It is clear from our review of the existing reports that public agencies largely ignore both the spirit and intent of the statute. While at least 65 CM/GC projects have been completed since 1997, the total number of reports is fewer than ten. In fact, while the statute directs public agencies to deliver the report to the Oregon Department of Administrative Services (DAS), no one in DAS, including the director, knew who was supposed to collect these reports and where they may be filed. In fact, no one is specifically tasked to oversee and handle the reports. Consequently, few reports are being done, and those that are being done do not meet the requirement that they be an "objective assessment" of the project. One done by Central Oregon Community College (COCC) barely meets the requirements of the statute by simply repeating verbatim the language in the exemption order in the affirmative.

The Oregon Secretary of States' Audit Division has audited several CM/GC projects, including the major prison projects and the library at Oregon State University (OSU). One audit found that the CM/GC contractor had over charged the state and or misspent millions of dollars on their project. None of these facts were included in the Department of Corrections (DOC) evaluation reports, which raise questions about the objectivity of these assessments.

There is no evaluation report on the OSU library project to compare to the state's audit because the Oregon University System (OUS) and its member institutions have since become exempt from most parts of Chapter 279, including section 103.

2.8 Prior PDS Research

Sanvido and Koncher [183], working for the Construction Industry Institute (CII), performed what appears to be the only comprehensive studies that compare project outcomes on the basis of PDS. Their study was based on data from CII members and was heavily weighted toward private industry with very few building projects, and fewer still public building projects. The data used in [183] was also used in [126] and [75] (in fact [183] is a summary report of [75]), and Vanden Bosch's presentation at the fall 1999 Northwest Construction Consumer Council [210] appears also to be based on the same data.

These reports all concluded that Design-Build (DB) was superior to CM/GC (which they call CM@ Risk, CM@R and CMR at different times) and both are superior to Design-Bid-Build (DBB). But these conclusions are based on weak analytical foundations. The principal statistical comparisons for cost and schedule growth are not statistically significant. Their "Construction Speed" and "Delivery Speed" statistics are significant but have little meaning in this context because speed is related to fast-tracking, and DBB projects are by definition not fast-tracked. The comparison is akin to comparing marathon runners against milers and then both against sprinters on the basis of how long their races take to run and finding sprinters superior because they finish in a shorter amount of time than either milers or marathoners! Furthermore, no data is presented and the statistical analysis does not include the variance or standard deviations of the data. In the Cost and Schedule Growth comparisons the reports compare medians because that method reduces the effect of outliers, but they fail to point out that the DB projects appear to have greatest range of outcomes, both over and under budget, which presents the greatest total risk. In addition, they also fail to point out that 75% of both the CM/GC and DB projects experienced cost growth; yet they make a point of stating that 90% of the DBB projects experienced cost growth.

Sanvido and Konchar [183] also compared the PDSs' on the basis of "Quality" perhaps in part because DB projects have historically been thought of as delivering lower quality results. They conclude that:

> "It is clear from these results that design-build projects achieved equal if not better quality results than other projects studied. In particular, design-build offered significantly better quality results than design-bid-build in all categories except that of interior space and layout. Design-build significantly outperformed construction management at risk in only one area, operation and maintenance cost."

But in fact the differences were quite small and there is no statistical data to show that the differences were statistically significant, in spite of the statement above. More importantly, however, is what Sanvido and Knochar [183] actually measured. Instead of using an objective measure, such as the "number of punch list items" or "dollar volume of warranty work," they asked owners to rate the quality on a relative scale: "perceived actual quality" compared with the "level of quality expected." This meant that if the owner had a low expectation of project quality and the project turned out only half as bad as expected, he'd rate it quite high. However, if the project was expected to be the highest possible quality, the highest score that the project could achieve is "as expected" (a 5 on the 10 point scale used) and from there, the scores can only go down. The conclusion that the DB projects deliver higher quality based on this test is misleading because they simply did not measure "Quality."

Gordon [101] and the Construction Engineering Management Program at OSU [56] have provided guides on how to select a PDS and Mulvey [150] has provided "A Contractor's Assessment" of project delivery trends, but there are no other analytical comparisons of PDS's based on project performance in the literature. The CII has performed benchmarking studies [207], but the most recent study [51] did not include any reference to PDS.

In another study, Henry and Brothers [108] compared DBB projects with indefinite delivery indefinite quantity (IDIQ) contracts used by the US Air Force under a system called SABER. However, these projects were all under $1 million and generally were in the $10,000 to $100,000 range, and often were small repair projects like Repair Latrine, Repair Showers and so on. Results from [108] are not comparable to this research.

2.9 Benchmarking

Benchmarking is a relatively new discipline, having been formalized at the Xerox Corporation by Robert C. Camp in the early 1980's and only brought into the academic literature in the late 1980's and early 1990's [194, 213]. Since that time, the field has grown rapidly and touched nearly every industry, including the construction industry. Organizations like the Associated General Contractors and American Building Contractors, routinely offer courses in Total Quality Management in construction that include benchmarking. The Construction Industry Institute located at the University of Texas, Austin, has made benchmarking one of their major areas of interest [207]. Jackson, Stafford and Swart [113] provide a bibliography of benchmarking books and papers, with a particular emphasis on the construction industry. Various others have used benchmarking techniques to analyze client satisfaction [4], the effectiveness of pre-project planning [103] and other applications [89, 130, 151].

The most intensive attempt to apply benchmarking in the construction industry has come from the Construction Industry Institute. Their study was of 203 projects from 22 owner companies and 25 contractor companies, for a total construction volume of approximately $11.5 billion [207]. This study focused on establishing "Best Practices" in the industry, such as "team building," "constructability," "safety," and "pre-project planning." The analysis in the regression model used project scores (on these metrics) as the dependent variable and "cost growth," "schedule performance," and "safety performance" metric scores. Unfortunately, many of these regressions account for a small portion of the variance in the data, with adjusted R^2 rarely greater than 25%, and in several cases, in the range of 10%-14% and lower. In some fields Adjusted R^2's of this magnitude are acceptable; however, in the public policy making environment on construction spending, where billions of taxpayer dollars are at stake, a decision based on a course of action that only accounts for 10% of the variance of the outcomes may be hard to justify.

2.10 Benchmarking in the Construction Industry

Benchmarking in the construction industry began in the early 1990's as an adjunct to Total Quality Management programs [89], and as one means to improve the contractor's standing with their principal customer, owners [44]. The Associated General Contractors of America (AGC), the construction industries' trade association, defined Benchmarking in a 1992 educational report as follows [3]:

> Formal benchmarking is the relatively new practice of identifying other companies, which have mastered a process and are world-class performers worthy of imitation. It has been described as "finding and implementing best practices." This business concept simply suggests that you look around and find success stories and learn from others.

In one report by AGC [3], they stated that the construction industry "has lagged behind other industries in implementing TQM." However, they continued, "part of that is the perception that TQM is for manufacturing only." Other authors [34, 160] have seen the situation in more dire terms, noting that, "the construction industry is still characterized by low productivity, fragmentation, divided responsibility, and conflicting objectives." Since then, several researchers have proposed models and metrics for evaluating and improving construction project performance.

Fisher [89] proposed quality management in the construction industry using the following measures to be benchmarked in the construction process:

Actual versus authorized costs
Schedule: actual versus estimated
Scope changes
Engineering rework
Construction labor: actual versus estimated
Field rework
Worker-hours per drawing
Project cost distribution
Field defects
Percent of rejected welds

The metrics used in the CII Benchmarking study by Tucker [207] included the following "critical few metrics:"

Cost Performance
- Budget factor
- Cost growth
- Phase cost factor

Schedule Performance
- Schedule factor
- Schedule growth
- Phase duration factor

Safety Performance
- Recordable Incident Rate (RIR)
- Lost Workday Case Incident Rate (LWCIR)

In more recent versions by the CII, including the 2001 Benchmarking Report [51], the organization has focused on the basic cost and schedule growth performance metrics and is no longer providing the regression analysis that was part of their 1997 study.

Ahmed and Kangari [4] list the following factors in their benchmarking study of "Client-Satisfaction Factors in the Construction Industry:"

Time
Client orientation
Communication
Cost
Response to complaints
Quality

Tam and Harris [199] propose a model for assessing past building contractor performance and predicting future performance using multiple regression techniques. This model was quite complex and included the following factors:

Internal Factors

Staff training program
Plant ownership policy
Size of the company
Quality of the management team – professional qualifications
Quality performance of the project manager
Past performance of the project manager
Contractor's experience in the type of job
Contractor's workload
Contractors past performance or image
Number of years in business
Origin of the company (domestic or foreign)
Amount of directly employed labor
Listed on the stock market
Decision making centralized in head office of de-centralized to the site
Contractor is client's subsidiary firm

External Factors

The architect/engineer
Architects of client's supervision and control of the quality of the work progress
Punctuality of payment by the client
Complexity of the project
Profitability

Jackson, Safford and Swart [113] provide a bibliography of "Current Benchmarking Literature," which appeared in a construction industry journal; however, it had no specific emphasis on the construction industry. Lema [137] gives a background perspective of benchmarking in the construction industry. Other construction industry applications include Kumaraswamy's [130] evaluation of mega-project performance, Hamilton's [103] benchmarking evaluation of pre-project planning and Munns and Ahmed's [4, 151] evaluations of project stakeholder relationships. Finally, Edwards [86] presents a guide to evaluating contractors past performance on federal projects, which is also considered by Nash and Cibinic [50, 155].

Chua *et al.* [48] studied critical success factors for construction projects, which built on the earlier and broader strategic factors considered by Sanvido *et al.* [182] and conceptual project management success factors of Pinto and Selvin [162]. Chua *et al.* [48] used a three level Analytic Hierarchy Process model that included 67 separate "success-related factors" in four broad "project aspects" that included: project characteristics, contractual arrangements, project participants and interactive processes. These four project aspects contributed to: budget performance, schedule performance, and quality performance. Ultimately these three measures contribute to project success. Cheng, Li and Love provide "Objective Measures of Partnering Outcomes" in [46] that include:

Cost-effectiveness
Quality
Schedule
Scope of work
Profit
Construction process (which includes safety and rework)
And, Others (which includes litigation)

In a separate benchmarking study, Brunso, *et al.* [33] used benchmarks: cost growth, schedule growth, and performance evaluations (quality) to benchmark project performance.

Gordon evaluates success factors differently in [101] by considering different "project drivers," such as the need for fast-tracking and allocations of risk, to select an appropriate project delivery system.

These benchmarking metrics, project success factors, and project drivers provide a starting point for our analysis of construction project performance. However, it is clear that with the large number of attributes in some studies, and small number in others, that there is not universal agreement on how to measure construction project performance nor is there agreement on which are the most important. Separating out the most important metrics and factors from those of less importance will be an important aspect of the research at hand.

2.11 The Data Envelopment Analysis (DEA) Methodology

DEA is widely used as a benchmarking tool in practice [19]. Its use is owed to the fact that DEA was developed as a tool to compare the efficiencies based on multiple inputs and outputs. The principal result of a DEA study yields efficiency scores, performance targets and criteria weighting schemes that are ideal for use in analyzing performance of specific operating units (defined in DEA as DMUs for Decision Making Units [42] - in the present research, construction "projects" are the DMUs).

2.11.1 Development of DEA

Charnes *et al.* [42] originally devised DEA as a method to derive relative efficiencies of different organizations or activities using multiple inputs and multiple outputs. The focus on comparative efficiency using multiple inputs and outputs was generated by the desire to measure factors other than financial performance. Early on, the methodology was thought to be particularly valuable in measuring public sector performance and other non-money-generating activities, since DEA can readily compare financial as well as non-financial data [42] (and combinations thereof [41, 200]).

Charnes, Cooper and Rhodes' original work [42], and Rhodes' dissertation research in the education field[26], were extensions of earlier single-input, single-output analysis by Farrell [88], and other methodological developments by Debreu [72], Koopmans [128] and others, including Charnes [38]. Seiford [186, 187], in tracing the evolution of DEA, found methodological formulations greatly similar to modern DEA, as far back as 1966.[27] According to Seiford, the intent of these earlier papers was to:

> "(1) Summarize Farrell's ideas; (2) provide LP formulations and efficient computational procedures for a variety of problems in technical efficiency including the multiple-output case; and give illustrative applications to (3) steam-electric generating plants and (4) aggregate census data."

However, from 1966 until 1978, the field of multiple attribute efficiency analysis, what is now DEA, went into a dormant phase until, Charnes, Cooper and Rhodes [42] brought the term Data Envelopment Analysis or DEA into the literature. In addition, they introduced another common DEA term: Decision Making Unit or DMU, to describe the different entities in the analysis. DMUs are the basic item being compared in the DEA model and have included: schools, banks, hospitals, and even professional baseball players. (However, before the current research, construction projects have not been used as DMUs in a DEA study.)

[26] The basis for which was laid in [43], as reported in [186, 187].
[27] Seiford references the "*Proceedings of the 39th Annual Meeting of the Western Farm Economics Association,*" where four papers recalling "Farrell's approach" to measuring technical efficiency were presented.

2.11.2 History and Background

The history and development of DEA has been documented by both Seiford [187] and Tavares [200], with bibliographies now stretching in excess of 3,200 citations. In brief, however, the five-year period following [42] witnessed a rapid expansion in the use of DEA to evaluate efficiency. This work was predominately in the education field [24-28, 40, 43, 164, 165, 195], medical field [14, 156, 190, 191] and other public sector and non-income producing activities [30, 39, 40, 52, 74, 140]. These early applications fostered a broad acceptance of DEA as an Operations Research/Management Science tool in the academic community.

2.11.3 Mathematical Development of DEA

The original formulation of DEA proposed to measure the efficiency of any Decision Making Unit or DMU, "as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity." This "Ratio" model is expressed mathematically, in the form of:

$$
\begin{aligned}
& Max\ H_0 : \frac{\sum_{r=1}^{s} u_r y_{r,o}}{\sum_{i=1}^{m} v_i x_{i,0}} \\
& S.T.: \frac{\sum_{r=1}^{s} u_r y_{r,j}}{\sum_{i=1}^{m} v_i x_{i,j}} \leq 1 \ \ \forall j = 1 \ldots n \qquad (2.2) \\
& u_r,\ v_i \geq 0; \quad r = 1 \ldots, s; \quad i = 1, \ldots, m.
\end{aligned}
$$

In the model, the x_{ij}, y_{rj}, are the known inputs and outputs of the jth DMU and the u_r's and v_i's are the variable (or criteria) weights to be determined by the solution of the linear program. That is, DEA allows each DMU_0, the specific DMU under consideration, to pick the weighting scheme that maximizes its efficiency score relative to all other DMUs, subject to the constraint that any other DMU, with an identical weighting scheme, cannot achieve an efficiency score greater than 1.

This formulation is non-linear; the linearization occurs by multiplying out the denominator of each inequality constraint and by adding a normalizing constraint (equation 2.3 below) to eliminate the ratio in the objective function. For details see [8].

$$\sum_{i=1}^{m} v_i x_{i0} = 1 \tag{2.3}$$

This addition yields the following formulations:

$$\begin{aligned} &Max\ z : \sum_{r=1}^{s} u_r y_{r,0} \\ &S.T.: \sum_{i=1}^{m} v_i x_{i0} = 1 \\ &\quad \sum_{r=1}^{s} u_r y_{rj} \le \sum_{i=1}^{m} v_i x_{ij} \quad \forall j = 1,\dots,n; \\ &\quad u_r,\ v_i \ge 0;\ \ r = 1\dots,s;\ \ i = 1,\dots,m. \end{aligned} \tag{2.4}$$

This formulation has been shown to be the linear programming "Dual" of what has become known as the input oriented CCR envelopment model formulation:

$$Min: \ \theta$$

$$S.T.: \sum_{j=1}^{n} y_{r,j}\lambda_j \geq y_{r,0} \qquad r = 1,...,s; \qquad (2.5)$$

$$\sum_{j=1}^{n} x_{i,j}\lambda_j \leq \theta x_{i,0} \qquad i = 1,...m;$$

$$\lambda \geq 0$$

Its complement, the output oriented CCR formulation, is given by:

$$Max: \ \phi$$

$$S.T.: \sum_{j=1}^{n} x_{i,j}\lambda_j \leq x_{i,0} \qquad i = 1,...m$$

$$\sum_{j=1}^{n} y_{r,j}\lambda_j \geq \phi y_{r,0} \qquad r = 1,...s \qquad (2.6)$$

$$\lambda \geq 0$$

The variable λ in these formulations is the vector of linear combinations of efficient DMUs used to construct the "virtual" efficient DMU for an inefficient DMU_0 under consideration.

The virtual targets resulting from DEA reveal pathways for improvement of the DMU under consideration to reach relative efficiency (i.e., reach the efficiency frontier). Figure 3 below depicts a one input two output, two-dimensional model. In this case the outputs are identified as only "Output Y_1" and "Output Y_2," and for the purposes of this example all of the inputs are assumed to be 1.0. Note the line denoted as the "Efficiency Frontier," which in this example is created by two DMUs. The DMU under consideration, DMU_0, is not on the efficiency frontier, therefore DMU_0 is technically inefficient. The "virtual target" for DMU_0 or "virtual DMU" is where DMU_0 would intersect the efficiency frontier using its current strategy of producing outputs in terms of the ratio of output X to output Y. This can be visualized in a two output DEA model shown below in Figure 3:

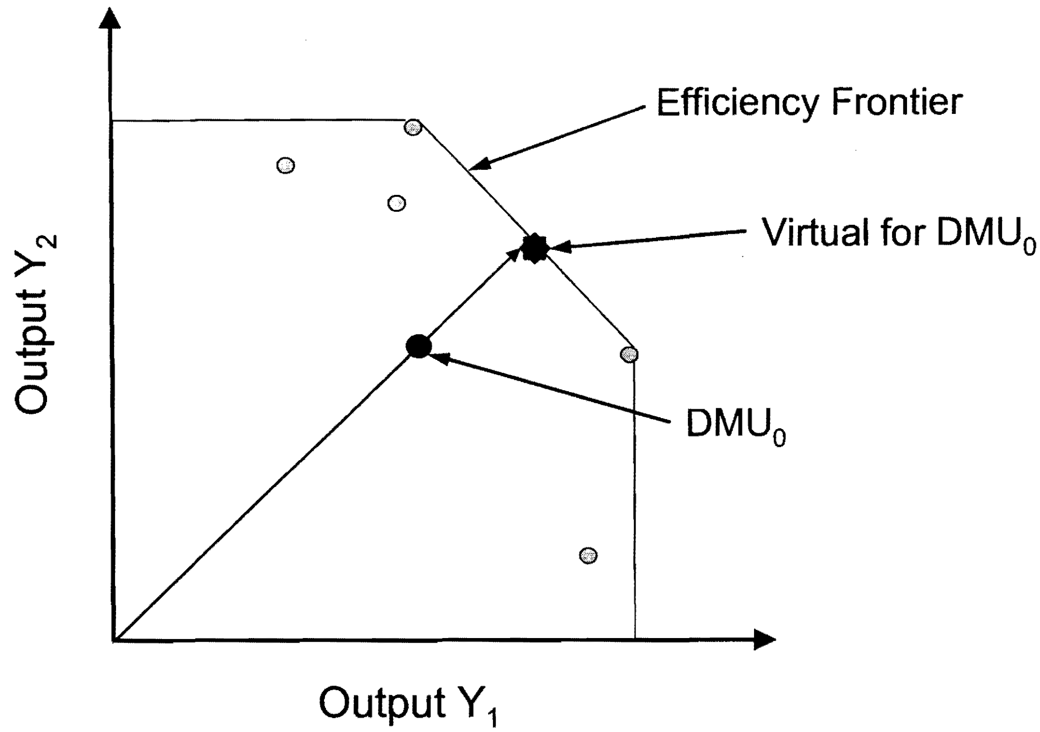

Figure 3: Example of a Virtual DMU in a two-dimensional DEA model

The λ vector for DMU_0 is made up of the linear combination of the only two efficient DMUs in this example. The efficiency of DMU_0 in the above example can be calculated as the ratio of the distance from the origin to DMU_0, to the distance from the origin to the virtual DMU located on the efficiency frontier.

In a constant returns to scale (CRS) DEA model, both input and output oriented models will give the same results (however, they will be reciprocals of one another). This is not true with all other DEA models such as Banker, Charnes and Cooper's [17] variable returns to scale (VRS) method.

2.11.4 Extensions of DEA

The original DEA model has been extended to allow for scale differences, to incorporate judgment, and recently to accommodate missing and imprecise data. Banker *et al.* [14, 17] first provided a method for comparing DMUs that were on vastly different scales (such as comparing a large "box" store like Home Depot or Costco in the same set as a small convenience store like a 7-11). The method, termed BCC (for Banker, Charnes and Cooper, the authors) results in a variable returns to scale or VRS model.

The next major contribution was the incorporation of judgment in the form of weight restrictions. That is, restricting the amount of weight, the magnitude of u_r's and v_i's in the model. This was originally brought into the DEA literature by Dyson *et al.* [84]. Roll *et al.* [167], Golany [98], Cook *et al.* [57-59], Ali *et al.* [6] and others provided extensions to this work that included the incorporation of weak and strong ordinal relationships. Thompson *et al.* [205] added the concept of "Assurance Regions" through multiplier bounds, and Wong and Beasley [223] formulated relative upper and lower bounds for inputs and outputs. Finally Allen *et al.* [7] provided a method for overcoming the problem of weakly efficient DMU by the addition of non-observed DMUs in the data set.

The preceding methods essentially limit or place boundaries on the basic DEA model. One of the reasons for implementing these methods is that the data or information may in fact be imprecise. Cooper *et al.* [62] was the first to publish a study with the term "imprecise" in the title; however, Golany [97] and others [61, 111, 141, 158] have studied "chance constrained" and "stochastic information" models since 1985. Cooper *et al.*'s [62] work expanded on the earlier methods, generalizing them for bounded imprecise inputs and outputs in the presence of assurance regions or AR-IDEA (Assurance Region – Imprecise Data Envelopment Analysis). The basic problem Cooper *et al.* [62] addressed is the fact that the underlying assumption in DEA that all the data are in the form of specific numerical values is simply not always true. Some data may only be known to be bounded within some range, while other data may be ordinal: good, better, best, for example, where we know that best > better > good, but we don't know how much difference there is. Still other data may be known only to exist between certain bounds, such as: USDOT gas mileage evaluations for certain types of automobiles: city driving the auto should get between 15 mpg and 18 mpg, and freeway driving the same auto is expected to get between 20 mpg and 24 mpg. Cooper *et al.* [62] used scale transformations and variable alterations to linearize the resulting IDEA model in the presence of ordinal and bounded information. This work was expanded in [63] using a dummy variable, the Column Maximum DMU or CMD.

Zhu [225] maintained that when weight restrictions are present, the resulting model in [62] remains non-linear. "Consequently, some of the efficiency results ... need to be revised." (This observation was in fact acknowledged in [62] and again by the same authors in [63].) In [225] Zhu gives a different method for incorporating imprecise method by converting bounded, weak ordinal, strong ordinal and ratio bounded data into exact data. Finally, Zhu shows that certain weight restrictions are "redundant and can be removed" in his transformed model.

These methods allow a researcher to incorporate data that may only be known within a certain range and both weak and strong ordinal preference structures. However, the fact that data may only be known to exist within certain bounds, such as the USDOT gas mileage estimates, in reality, a specific automobile will achieve a specific rating. Another method for evaluating bounded imprecise data, proposed by Anderson and Williams [9], is to evaluate DMUs for their worst and best possible efficiency ratings by simply comparing each individual DMU under four alternative formulations:

Max DMU_0	Max DMU_i $\forall$ i $\neq 0$	Optimistic Structure
Max DMU_0	Min DMU_i $\forall$ i $\neq 0$	Benevolent Structure (yields highest rating)
Min DMU_0	Max DMU_i $\forall$ i $\neq 0$	Malevolent Structure (yields lowest rating)
Min DMU_0	Min DMU_i $\forall$ i $\neq 0$	Pessimistic Structure

Table 3: Imprecise Formulations by Anderson and Williams [9]

The terms Max $DMU_{0 \text{ and } i}$ and Min $DMU_{0 \text{ and } i}$ are rules to maximize and minimize the DMU data where missing data are present. For example, in the case of Max DMU0, if DMU_0 is missing an *output* datum, the missing datum would be replaced with the maximum amount found in the peer group. If DMU_0 is missing an *input* datum, the missing datum would be replaced with the minimum amount found in the peer group, thereby maximizing the DEA score for DMU_0.

In the "Optimistic" formulation, all DMUs are given the benefit of the doubt, and when data is missing, the missing metric is replaced with the best data for that metric (the largest number output and minimum number of input) for each found in the peer data set. This formulation assumes that all DMUs do the best possible in all missing data metrics. In the "Benevolent" formulation, DMU_0, the DMU under consideration is given the "Optimistic" data for all missing data metrics, whereas the comparator DMUs are all given the opposite or minimum data for each missing data metric. This formulation will result in the highest possible score for DMU_0 because while it assumes DMU_0 has the maximum value for each missing data metric, the comparator DMUs all score the worst possible in the missing data metrics. In the Malevolent formulation, DMU_0 is given the minimum data for each missing data metric, whereas the comparator DMUs are given the maximum. This will give the lowest possible score for DMU_0 and is essentially the opposite of the "Benevolent" formulation. Finally, the "Pessimistic" formulation assumes that when data is missing, the DMU is assigned the largest possible inputs and the lowest possible output data (including zero output.)

In the case of this research we know from the architect members of the Expert Panel that the boundaries of the imprecise inputs are roughly as follows:

Conceptual Design	10% to 40%
Schematic Design	30% to 70%
Preliminary Design	60% to 90%
Final Design	90% to 100%

Table 4: Experts Design Classification Ranges

Which can be represented graphically as in Figure 4 below.

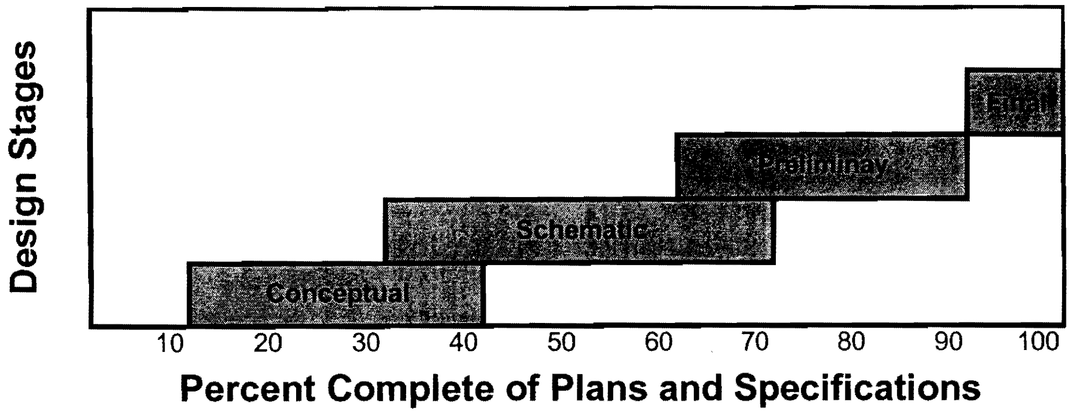

Figure 4 Design Stages in Percent Complete of Plans and Specifications

We can now perform a simple one-input one-output example using of the imprecise data formulation given above, using the data obtained from the Expert Panel and assuming a single output of 1.00. Since there is only one input and one output there is no need to use the DEA computer model, we simply need to calculate the high and low input scores for each DMU under the different conditions (noting that the outputs remain the same) as given in Table 5.

	MODEL INPUTS			
DMU	**Design Completion**	**Low Input**	**High Input**	**Output**
A	Conceptual	0.10	0.40	1.00
B	Schematic	0.30	0.70	1.00
C	Preliminary	0.60	0.90	1.00
D	Final	0.90	1.00	1.00

Table 5: Example of input-output data for the imprecise model described above

Next, calculate the efficiency scores by dividing each DMU by the highest DMU score for the specific formulation. The benevolent and malevolent formulation DEA scores for each of the DMUs in the example above are given in Table 6:

DMU	Design Completion	Best Score O/I_{low}	Lowest Score O/I_{high}	Benevolent Efficiency Score	Malevolent Efficiency Score
A	Conceptual	10.0	2.50	1.00	0.75
B	Schematic	3.33	1.43	1.00	0.14
C	Preliminary	1.67	1.11	0.67	0.11
D	Final	1.11	1.00	0.44	0.10

Table 6: DEA scores for DMUs presented above

We learn from this example that the formulation given by Anderson and Williams [9] is sensitive to the range of the imprecise data. In this research, the output data is constrained to a range of plus or minus eight to ten percent, an imprecise input must have a smaller range in order for this model to have much meaning. Since this is not the case with the construction building data, the formulation above cannot be used here.

In addition, the model presented above prescribes a method for comparing DMUs when one or more data types is missing entirely. The proposed formulation compares DMU_0 which has some missing x_i's or y_r's against the set of DMU_j's also missing the same x_i's or y_r's. This is another form of the "Benevolent" formulation where DMU_0 is given the benefit of the doubt, and whatever the missing x_i's or y_r's may represent, the comparator's performance on those metrics are not used against DMU_0. Other variations suggested by Anderson and Williams [9] include replacing the missing x_i's or y_r's with either the minimum or maximum values of those x_i's or y_r's in the data set. These are "Optimistic Benevolent," and "Pessimistic Malevolent" formulations consistent with the plan are presented in Table 3 above.

2.12 DEA Compared to Regression Models

In discussing confidence intervals for efficiency estimates comparing DEA with statistical methods like regression, Horrace and Schmidt [110] state that "deterministic approaches (e.g., DEA) produce efficiency *measures*, while statistical approaches produce efficiency *estimates*." By this, they mean that DEA produces a measure of technical efficiency that is measured against a virtual target, or efficient producer, that lies on the linear production frontier and utilizes the same weighting strategy as the DMU under consideration. However, unlike stochastic methods, DEA does not directly yield an estimate of the accuracy of the measurement in terms of confidence limits, which was addressed by Horrace and Schmidt [110]. More importantly, the idea of measurement accuracy versus statistical estimate is a key difference in benchmarking approaches using DEA versus Regression and other statistical methods.

The virtual targets resulting from DEA reveal pathways for improvement of the DMU under consideration to reach relative efficiency (i.e., reach the efficiency frontier). Figure 3 above depicted a one input two output, two-dimensional model. In that example the outputs are identified as only "Output Y_1" and "Output Y_2," and all of the inputs are assumed to be 1.0.

The virtual DMU tells the analyst what DMU_0 needs to do to improve the efficiency frontier. The distance from DMU_0 to the efficiency frontier at the virtual DMU is also used to calculate the efficiency of DMU_0 (here DMU_0's efficiency is calculated as the distance from the origin to DMU_0 divided by the distance from the origin to the Virtual DMU).

Figure 3 also illustrates an important difference between DEA and statistical methods like regression in that the virtual target is determined by strategy employed by DMU_0, which may be quite different from the strategy employed by any other DMU. In addition, from DEA we can evaluate different strategies that may allow us to reach the efficiency frontier. In Figure 3, for instance, DMU_0 may decide that instead of pursuing the current strategy, perhaps he should simply concentrate on increasing one or the other outputs (X's or Y's).

In a construction setting, the project or company manager may determine that she should shift her strategy, for example: to pay more attention to quality or safety, perhaps even at the expense of cost or schedule performance, in order to reach the efficiency frontier.

Benchmarking is defined as the "search for industry best practices ..." [137], and some of the drawbacks to regression analysis for benchmarking are that: while the factor weights are derived from the data, as in DEA, the resulting regression model prescribes only one "best practice." The regression model results in a single linear extrapolation of all the data points, which is used in comparing the performance of individual entities in the analysis.

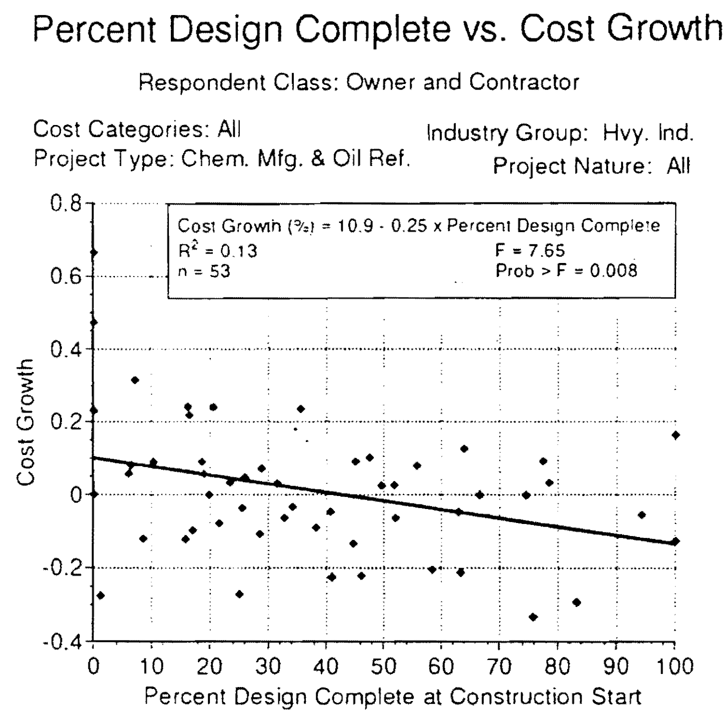

Figure 5: Regression of Cost Growth v. %Complete Design [207]

In Figure 5, the benchmark model for Percent Design Complete vs. Cost Growth prescribes only a single trade-off between the two metrics (Cost Growth % = 10.9 – 0.25 × Percent Design Complete) that all projects are compared against. DEA allows for a wider range of trade-offs between input and output variables, reflecting the wide range of strategies practiced by individual organizations.

Secondly, the "best practice" linear extrapolation includes in its derivation both the best and the worst producers, whereas DEA compares all producers against only the best. By including poor performers so intimately in the model, the benchmark is inherently weaker. To say that a project performed above the benchmark line in Figure 5 is merely saying that the project beat out half its competitor's! In DEA, the statement that the project performs at or near an efficiency of 1.0 means that the projects is clearly performing at the top or near the top of all competitors in the analysis. These are vastly different statements about project performance.

Finally, as seen in Figure 5 below, from a CII benchmarking study [207], these methods fail to account for a significant differences in performance. That is, the adjusted R^2 in several cases was very low, on the order of 13% as shown in Figure 5, with a wide and unexplained variation in data points. According to Givens [95] this problem is a great concern of the Construction Industry Institute and has caused them to rethink their benchmarking approach.

2.12.1 DEA Compared with other Production Efficiency Measuring Methods

Linear regression models are not the only methods used to evaluate efficiency; they are perhaps the most widely used, and particularly in construction industry benchmarking studies in the literature [3, 4, 199, 207]. The second most commonly used methodology for benchmarking in the construction industry involves presentation of simple statistics of the base data such as histograms [89] and box plots [103]. Others have used fixed weight functions [130], correlation analysis [12], and ANOVA [4] to further analyze construction industry data. However, each of these methods has drawbacks with respect to the goals of benchmarking and estimating production efficiency, the principal drawback being that the poor performers have the same influence on the models as the best performers do. DEA on the other hand does not suffer from this problem, nor is DEA susceptible to problems with covariant metrics in the model because they have no effect on a DMU's technical efficiency score.

As noted above, since benchmarking is the "search for industry best practices ..." [137], the best way to do so is to compare the entity under consideration against the best performer [89]. By contrast, statistical methods generally include all performers, the best as well as the worst, in the analysis as discussed in 2.12 above. This inclusion of poor performers in the analysis is likely to cause the model to underestimate the production efficiency of high performers and overestimate the efficiency of low performers. Also, Thanassoulis [202] found that DEA did a better job of estimating production efficiency than regression models; however, he also found that "regression analysis offers greater stability of accuracy."

As a method for estimating relative production efficiency among different producers, DEA has been found to be superior to other multi-variate techniques [16, 18]. These studies utilized simulated data from underlying stochastic production functions and tested DEA against Corrected Ordinary Least Squares (COLS) analysis for different sample sizes and five different production functions. They found that "DEA performs better for all non-classical inefficiency estimates, even with relative high measurement errors" and "DEA provides surprisingly accurate estimates for the small sample sizes for all cases in the experiment" [18]. DEA was further compared against more common Ratio Analysis tools for performance measures (such as financial ratios) and DEA was found to be superior for setting targets for improving performance of operating units [203], which is in essence what benchmarking concerns itself with.

Simulation was used as a data generating process for testing relative performance of DEA and regression techniques by Banker *et al.* in two separate studies [16, 18].

Simulation is a technique that could be used in benchmarking studies if the underlying production functions were well understood. Unfortunately, the process of management decision making on construction projects is not known in the rich detail required for simulation. Furthermore, the structure of the contract or contracting method, the specific nature of the project and the demands of the owner will influence the behavior of the managers and decision-makers, making the process extremely difficult to model. DEA, by contrast, evaluates the ex-post decision-making and management processes.

2.12.2 Current DEA Application Areas

As noted earlier, Seiford [186] and Tavares [200] have traced the evolution of DEA and provided comprehensive bibliographies of DEA papers. Tavares [200], which is the more recent and includes papers presented at conferences as well as research publications, books and dissertations, contains more than 3,200 individual entries. In addition, [200] includes both author and key word statistics. The keyword section documents the DEA applications in the various industries, organizations and economic sectors. The construction and building industry applications are limited to just a handful of citations including building sector research [184], road construction vehicle management [109, 157] and nuclear power plant construction times [189]. None of these applications proposes to evaluate construction contractor efficiency or performance benchmarking. None of the references in [200] appear to be applications of construction contractor performance evaluation. Only one paper is listed with the key word "competitive bidding" (a paper that deals with electrical utility contracts in Japan) and another under "bidding" (a paper entitled "Bidding Efficiencies for rights to car ownership in Singapore"), neither of which are construction related studies.

This study is the first application of DEA to construction project performance. Furthermore, while the vendor selection references cited above do present certain similarities to this proposed study, [214] is situated in the JIT manufacturing environment and [122] is an application of technology selection in the high-technology sector. However, it is interesting to note that in one application by Weber [214] on vendor selection in manufacturing, the principal factors considered in the study were price, quality and delivery time, which are consistent with those used to measure construction project performance in several studies, as noted above.

2.13 Statistical Methods Using DEA

Statistical validation and hypothesis tests using DEA efficiency scores has been an area of interest within the DEA literature for some time [15]. This is perhaps an obvious concern, given that efficiency scores (in the input oriented case) vary from 0 to 1.0 and therefore cannot be normally distributed and in fact have been found to be "significantly non-normal" [188]. Some, like Gong and Sickles [100], have even labeled DEA to be "non-statistical." However, [15] surveys the literature concerning the evolution of statistical methods in DEA and develops an inefficiency estimator that can be used to construct statistical tests. Other researchers have simply accepted the fact that DEA produces non-normal distributions and apply ordinary least square (OLS) regression methods to the data using a dummy variable [188].

2.14 Non-parametric Comparison Methods

Since DEA is a non-parametric method that produces results that are not normally distributed, this research will use non-parametric methods to compare the DEA model efficiency score results.

Non-parametric methods were devised to provide statistical tests for non-normally distributed and more generally, distribution-free populations [77].

The Wilcoxon-Mann-Whitney rank sum method tests if two random samples taken from populations that are not normally distributed could have come from populations with the same median [78]. The Kruskall-Wallis rank sum method tests if K random samples could have come from K populations with the same median. These methods could be used to test hypotheses that the two sets of projects are drawn from different populations by using the mean of one group to test the other.

The Spearman rank correlation test is a method used "to investigate the significance of the correlation between two series of observations obtained in pairs" [120]. In this method, observations obtained in pairs, x_i and y_i, are assigned rank numbers 1, 2, ... n in order of increasing magnitude. The differences in the rank numbers of the pairs are then used to produce a test statistic (either Z for $n \geq 10$ or r, otherwise) that can be used to determine the significance of the correlation between the two groups. The limitation to this method is that it also assumes that the groups are drawn from continuous distributions and that the observations are taken in pairs. These limitations also hold true for the Kendall rank correlation test (paired observations) [120].

The limitation that the groups of observations are drawn from continuous populations is not necessarily a fatal flaw that voids their potential use; in fact, DEA does produce continuous population results that are bounded by 0 and 1. Several researchers have used statistical methods with much stronger assumptions of normality in DEA analysis as noted in Section 2.13 above. The important point is that we need to understand and deal with the effect of discarding the continuous and non-normality assumptions. These effects are generally that the confidence intervals will differ from the nominal levels specified in the analysis [77]. We acknowledge this to be the case and may have to set higher than normal confidence limits in order to justify rejecting hypotheses based on these tests.

2.15 Multiple Perspectives and Stakeholder Analysis

Section 2.12.1, states that the construction management decision making process is not known in rich and sufficient detail to allow us to simulate the production process or prescribe a production function (or set of production functions) to evaluate project efficiency. However, this is not an uncommon problem as Linstone [142] points out:

> Decision making inherently involves organizations and individuals, whose perspectives are very different from those of "rational" system analysts.

In order to understand the decision making process, Linstone recommends going beyond the technical perspective that our quantitative models help us to understand and evaluate also personal and organizational influences that weight in the management and decision-making processes.

Jones [116] states that the essential premises stakeholder theory is as follows:

- the [public contracting agency] has relationships with many constituent groups ("stakeholders") that affect and are affected by its decisions;
- the theory is concerned with the nature of these relationships in of both process and outcomes for the [agency] and its stakeholders;
- the interests of all (legitimate) stakeholders have intrinsic value, and one set of interests is assumed to dominate the others;
- the theory focuses on managerial decision making.

Construction projects affect and are affected by a number of stakeholders both directly and indirectly. These include contractors, subcontractors, designers, politicians, bureaucrats, and the public taxpayer to name a few. The managerial choice of which PDS to use on a specific project, while guided by statute, is a managerial decision that has consequences for the stakeholders. The attitudes and opinions expressed by the stakeholders (by effective lobbying) can impact the agencies' decisions, and regardless, their interests as they see them "have intrinsic value," especially when reconciling the data analysis with the actual decisions made.

It is clear that the choice of PDS may be influenced by personal preferences as well as organizational and stakeholder pressures and in spite of the fact that the statutory construction requires cost to be the major (essentially only) decision factor. For example, a construction manager for a public agency might have significant organizational pressure to avoid conflicts or litigation, and therefore may choose CM/GC rather than a DBB on the belief that it will result in fewer claims. Also, it is possible that personal attitudes and biases can affect contractor selection method choice, in particular, the desire to hire or veto participation by one or more specific contractors.

Eliciting honest perspectives from the project players is difficult [13], particularly in this situation because public managers may have reasonable fears that disgruntled contractors would use any information about a selection process to discredit the official and overturn a selection decision or even sue the official under Oregon law. Furthermore, one Expert actually stated that his company's main concern was making sure that the option to use CM/GC as a PDS on public projects remain available to public agencies, pretty much regardless of the data indicates, because they believed in the process and believed that it resulted in better projects, regardless of what the data analysis shows. Another stakeholder noted that the principal benefit of negotiated procurements is that they don't have to work with people they don't like.

3 Research Design and Data Collection

In this chapter we discuss the research design and data collection required to address the principal research questions: is one PDS superior to the other, and if so, under what circumstances. We document the many steps and many of the challenges that were encountered both internally and externally while trying to extract the proper information for that part of our analysis. The data collection for the stakeholder and project comparison research questions is contained in their respective chapters.

3.1 Research Models

The first order of business is to agree on a basic model that can be constructed to test the research questions. DEA was chosen as the methodology for this study because DEA allows for a wide variety of inputs and outputs of a system and assumes no specific method for transforming inputs into outputs. Therefore, the model for construction project management is a process of taking inputs or resources and managing them to produce outputs. Chua [47] proposes a similar model for management decision making in the construction bid market, where the inputs are both external and internal factors, and the output is the bid markup. Chua [47] lists 51 possible input factors in his model – some of which were selected by the Expert Panel in the model proposed used in this research.

3.1.1 Contract Information Model

The diagram in Figure 6 shows inputs on the left side and outputs on the right. Inputs can include a number of things such as resources and information. The public construction industry uses a legal construct that assumes that all the information necessary to bid a project is contained in the plans and specifications supplied by the owner [175] at page 11-32 (along with common general knowledge of the project site, the owner, the designer, and weather patterns during the course of the project). The applicable competitive bidding theory assumes that the various bidders have the same information upon which to base their bids, and that the actual true project costs will likewise be equivalent. It is generally assumed for the purposes of theoretical analysis that this information is generally symmetric, that is that all bidders have access to the same information prior to bidding, but this is only partly true. Some bidders will know the owner agency and its management style better, while others may have personal experience with the site or the designer. In any case, for the purposes of this discussion, we assume that the information presented to a contractor at the time of developing his contract price for the different PDSs can be thought of as depicted below.

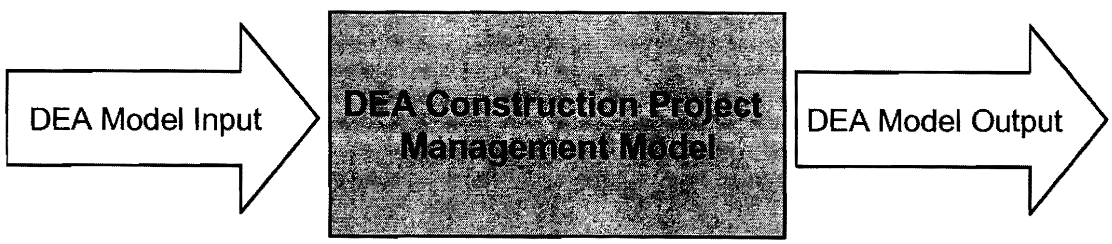

Figure 6: DEA Construction Project Management Sequence Diagram

Figure 7 thorough Figure 10 depict different theoretical sets of information in the public construction contracting environment.

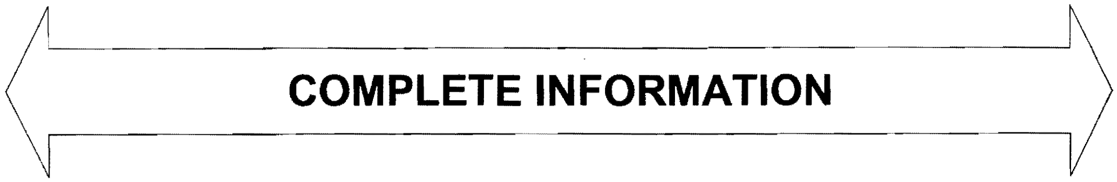

Figure 7: Complete Information for a Prospective Project

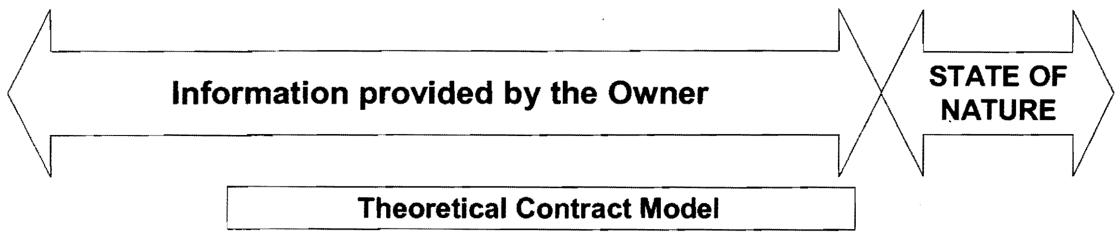

Figure 8: Theoretical Information Models as a basis for Contract Price

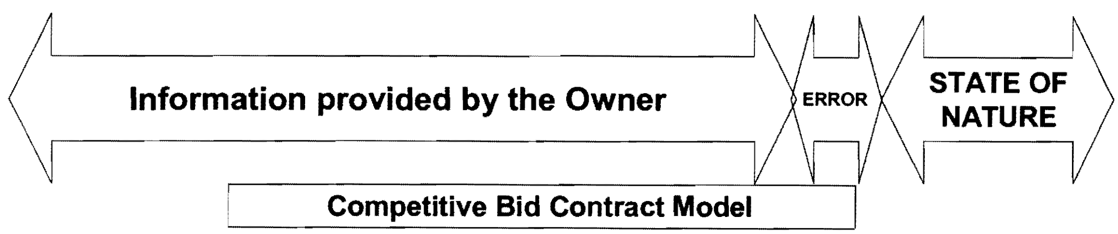

Figure 9: Competitive Bid Model as Experienced in Practice

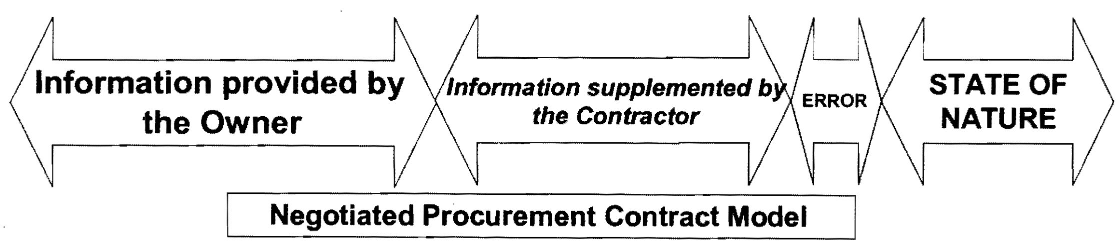

Figure 10: Negotiated Procurement Contract Model

The amount of information available to a construction contractor at the time pricing or selection is required is never complete. Figure 7 indicates complete information, which includes knowledge of future states of nature as well as no errors in interpretation of the data by the contractor; clearly, this ideal is never achieved.

Figure 8 depicts the theoretical DBB competitive bid model of information upon which virtually all contracts and construction law are based. It provides that the basis for all competitive contracts or scope of work for all competitive contracts is based solely on information provided by the owner (typically by and through their consultant architects and engineers) and the State of Nature (SON). The SON concept is based on an acceptable or typical performance of the SON, usually meaning the "weather" but also includes such things as normally expected underground and hidden conditions. The amount of information regarding the SON can be increased by expending time, effort and funds to make better predictions about the SON, such as paying for the consultants to perform underground soils investigations. This will reduce the size of the SON arrow since is reduces the unknown portion of the SON with known "information." But some SON's, in particular the weather far off in the future, are outside the bounds of investigation, which in particular affects long term projects that are the subject of this study. The standard in the construction industry is to use the "average" SON as a benchmark for what the bidders should expect to encounter. Only if the actual SON of the weather is abnormally adverse will there be an amendment to the contract.

Figure 9, the "Competitive Bid Contract Model," more accurately reflects the actual state of information in the competitive contract method, where the actual information provided at the time of pricing is less than complete information, by both the SON and "Errors and Omissions" in the information provided by the owner. This leads to the contractual provisions in most construction contracts that allow for amendments to the contract based on errors or omissions.

Figure 10 is the CM/GC model where the amount of information presented at the time of selection or pricing is admittedly less than complete than that which is provided in the DBB model. This model recognizes the construction contractor's ability to exercise judgment and requires him to fill in the gaps between the amount of information given and what is required to derive a contract price. The owner is able to reduce the amount of information required at the time the price is agreed on directly proportional to the increase in information supplied by the CM/GC contractor. However, in order to obtain Building Permits and Certificates of Occupancy from local building officials, the plans and specifications for the building under this model must still meet the rigorous standards set by the building code officials. This means that the owner will very likely spend just about the same amount of money for the design work, and perhaps even more, than he would under the DBB PDS, but the DBB PDS requires that the plans and specifications be complete prior to selection of the contractor [56].

3.2 Survey Instrument

The first major challenge was to design a survey instrument that would be accepted by the sources, easy to use and fill out, and provide all of the information that was sought in the study.

3.2.1 Expert Panel Work – Defining Success Measures & Constraints

As we had proposed to do, we recruited a panel of industry experts to help define, "what makes a good project good?" "How is it measured?" And "what challenges must a contractor overcome in order to produce a good project?" The underlying process was similar to a Delphi method [13, 143], modified to two rounds, with an initial set of possible attributes to consider. In the second round, the initial responses were aggregated into like groups by the author and the Experts were asked to confirm or reject these synthesized attributes in a process described by [13] at page 247 and [48].

The Expert Panel consisted of roughly ten architect/engineers, ten owners, and ten construction contractor representatives (see Appendix B). All of the project participants were senior level management personnel, project managers, attorneys, partners, company owners and two elected officials. The members were selected and recruited because they represent a large segment of the industry that has a lot of experience in both DBB and CM/GC project delivery methods. In addition, we recruited construction contractors to participate in this part of the study in order to help educate them and make them a part of the data collection phase. Our intent was clear: if we could get a few very influential construction firms to give us this information, we could probably leverage their support to obtain the support from others in the state.

3.2.2 Initial Measures Data Collection

On September 22nd, 1998 a package was sent to each of the Expert Panel member's.[28] This package contained a cover letter thanking each member for their participation and explaining the study goals and what data we sought from them at this point; a detailed 24-page explanation of Data Envelopment Analysis and benchmarking in the construction industry, drawn from the literature review; and two data collection sheets and return envelope. The data collection at this point was relatively straightforward; we asked them to indicate what they considered to be "Construction Project Outputs or Success Measures" and "How Best to Measure the Project Output" on one sheet and what are the "Construction Project Inputs or Project Resources or Constraints" and "How Best to Measure the Project Input" on the other.

The Experts were advised that they need not fill out the entire table of ten rows, but to "only include the attributes you feel are important in measuring a construction project's efficiency." In addition, check-off boxes at the bottom of the page entitled "Contractor," "Consultant," and "Owner" were included to evaluate the responses on a stakeholder basis (but no other identifying marks were requested or taken, so that the responses would be anonymous).

Of the thirty packets that were sent out, fifteen were returned by mail, two were hand delivered and four participants sent email versions of the request back. Three other packets were returned because they did not have the correct address, two of these three were corrected and sent out but not returned. The other final packet, which was to have

[28] See Appendix B for a complete list of Expert Panel Members

gone to a Seattle based national contractor's vice president of estimating and purchasing was returned too late to be re-sent.

An analysis of these initial responses produced a mildly surprising set of results: there was no significant difference between the different stakeholder groups (architects/engineers, owners and contractors) as to the measures of performance, and only very little difference as measures of resources and constraints. One of the more unusual consistencies was that all groups felt contractor profit and minority contractor participation were both positively correlated with project performance and efficiency. It is not intuitive that owners and architects would care much about contractor profit on a project, since neither would benefit from that increased profit. Likewise, it is not intuitive that contractor's unanimously felt minority participation was an important output to measure, given that social policy is typically outside their business considerations.

We do not mean to imply that every response from every participant was the same, however, and so the next step was to focus the Expert Panel on refining the metrics and agreeing on how to measure each metric.

3.2.3 Second Expert Panel Survey

The following table reflects the second step in referring the metrics work with the Expert Panel.

Construction Project Outputs

Metric	Measure	Include?	Rank
Financial Performance • Budget Performance • Project Profitability	 % over/under Budget % profits	 Yes No Yes No	
Schedule Performance • Project Completion • Milestone Completion	 Original Planned / Actual Schedule Original Planned / Actual Performance	 Yes No Yes No	
Quality of Work • Workmanship • Materials & Equipment • Met Performance Criteria	 Number of Punch List Items Amount of Warranty Work Rating on 1 – 10 Scale	 Yes No Yes No Yes No	
Minority Participation • Met Project Goals	 % Participation / % Goal	 Yes No	
Satisfaction of Project Participants • Owner Satisfaction • Consultant Team Satisfaction • Contractor Satisfaction	 Ask to Rate Ask to Rate Ask to Rate	 Yes No Yes No Yes No	
Other:			

Table 7: Second Output Metric Data Form

A second sheet, in a similar format for Construction Project Inputs, and a third sheet, which is shown below and is an example of a completed form, was included in this survey.

EXAMPLE OF COMPLETED METRIC RATING FORM (FYI)

Metric	Measure	Include?	Rank
Financial Performance • Budget Performance • ***Add: Profit Performance***	• % over/under Budget • ***% Profit***	Yes	1
Schedule Performance • Project Completion	• Original Planned / Actual Schedule	Yes	2
Quality of Work • Workmanship	• Number of Punch List Items.	Yes	3
Minority Participation • Met Project Goals	• % Participation / % Goal	Yes	5
~~Satisfaction of Project Participants~~ ~~• Owner Contractor Relationship~~	~~• Ask to Rate~~	No	0
Safety Performance • Safety Performance	• # of Accidents or Claims	Yes	4
Other Items not listed above that you feel are important: • • *PUBLIC ACCEPTANCE* • • • • • •	• • AIA AWARDS, % OCCUPIED • • • • • • •	YES	6

Figure 11 Picture of an example of a completed data collection sheet

Note that the rankings were initially intended to be used to restrict weights of the inputs and outputs; however, this approach proved unsuccessful and was not used in the final model.

A smaller proportion of these forms were returned compared to the first survey, and a further step of taking the form directly to Expert Panel members over lunch was necessary to better define the metrics, the measures. From these one-on-one meetings, ideas emerged regarding how to deal with the sensitive profit and safety data discussed below. Following this step, we had a pretty clear picture of what the initial DEA model would look like, and what our data collection survey instrument would have to include.

3.3 Project Data Collection

3.3.1 Projects Sample

It was the intent of this research to obtain data on as many projects as possible, with an ultimate goal of identifying all projects built in Oregon during the study period and obtaining data on each. It was never the intent of this study to obtain a statistical sample of the population of all projects, and that is a limitation of the research. However, 407 projects meeting the study requirements were identified (215 were actually used in the model) which, for a small state like Oregon, probably represents the majority of public building projects constructed during that period. While it's quite difficult to determine with certainty the exact number of projects built during the study period, we were able to perform a number of checks to confirm the rationale for our assumption that the Oregon database does in fact represent the majority of large public building projects during the study period. These include the following:

- We sought data from every building contractor in Oregon whose bonding capacity and public sector work history would suggest that they could and would perform the type and size of projects of concern in this research.
- We sought data from every city, school district and public agency in Oregon that would normally have the ability to fund projects of the size concerned with this research.[29]

[29] It should be noted that Oregon's population is concentrated in ten of its 36 counties and 50% of the population resides in the tri-county metropolitan area of Portland. Of the ten largest cities in Oregon, only two are located outside the Willamette valley, and both of those cities and their respective school districts were contacted for this study.

- A cross-check was made between the Oregon database, that was obtained as described above and the state of Oregon's bonded capitol improvements program funds authorized by the Legislature for the 1989 biennium through the 2001 biennium and all 14 of the 14 funded projects were accounted for in the Oregon database.
- Finally, for this study to have missed a large proportion or majority of the projects of similar size and type used in the study, we would have had to have missed more than a billion dollars in public construction[30], in a state that only received tax revenues of $4.66 billion in total for 2001 (exclusive of property taxes), with the largest proportion of these funds going toward K-12 Education, Human Services, and Public Safety [216].

Based one these observations we conclude that we have in fact obtained the majority of large public building projects constructed in Oregon during the research period.

3.3.2 Types of Data to be Obtained

Nearly all of the data that was sought could be considered "Public Information" and likely could be subject to the Oregon Freedom of Information Act (ORS Chapter 192), but it was clear that we would meet with resistance from the contractors on certain questions about the amount of profit earned on the project and project safety, which was not public information. While both profit and safety metrics were unanimously considered important project outputs from all Expert Panel members these are obviously sensitive

[30] The smallest projects in the database were about $2.5 million and missing 400 projects would be $1 billion in public spending.

questions for businesses to answer, especially if they thought the information would be used against them by their competitors in the future. And while we may have been able to obtain inside company records through the Oregon Secretary of State's office (by invoking the audit clause included in most if not all public construction contracts) or by filing a request under ORS Chapter 192, that kind of aggressive approach would have been time consuming, costly and would likely have evaporated any support the study would have in the construction community, therefore we dismissed it as a possible strategy.

In order to obtain sensitive information from the contractors, our strategy was first to recruit several senior management from construction firms to serve on the Expert Panel. This would allow them to tell us how to collect the information in a way that would be most palatable to them. Secondly, and perhaps most importantly, we offered complete confidentiality of all project information we received, and furthermore that all the project identification would be randomized so that no person or organization outside our research team would be able to decipher the data associated with a specific project. Finally, working with the contractor Expert Panel members, we devised a way to portray the information without asking revealing sensitive information. This was done by asking contractors to give us final profit numbers relative to expected profit at the time the contract price was established.

The same approach was followed with cost and schedule control metrics, asking what was the original total budget divided by the final amount actually paid to the contractor (cost control) and what was the original project time divided by the actual performance period (schedule control).[31] In general, this worked fairly well; however, some contractors did not fill in all of the information, and it was clear from they way they did answer the questions that they were confused. Some answered by giving us the original and actual performance periods, for example: original: 10/1/96 to 12/1/97, actual: 11/1/96 to 2/15/98. That information allowed us to calculate the correct metric. Others answered by stating simply: On Time (which yields a metric of 1.0); or by stating some amount of time late or early, which made the calculation more difficult without additional information.

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[31] In the case of costs we actually asked what the original and final costs were. We did this for two reasons, first as a check on the source's math and second because we would later use the final cost figure to calculate cost per square foot measures. On the schedule control metric, we later found that we would probably have been better off simply asking the questions: what was the original contract period and what was the actual performance period – we received the information in that form from several contractors and it provides better information to us in any case. In fact, when we performed the data collect by going to owners' archives and searching the files ourselves, we collected the data in that form.

Project:«Project_Name»	Architect:«Architect»	Year: «Year»			
Project Type (check all that apply)					
New Office Building		New School Building		Major Remodel of Existing Bldg	
New Hospital or Medical Bldg		New Industrial		Mixed: New and Remodel	
New Corrections: Jail or Prison		New Institutional		Other	

Did the Owner hire a separate Construction Manager: Yes________ No________

Project Size:________________ sf Original Budget: $ ________________ Final total billing: $ ________________

Contract Type: Lump Sum Bid______________ or Negotiated Procurement (CM/GC)______________

Metric	Measure	How to Calculate	Response
Financial Performance • Budget Performance • Project Profitability	% over/under Budget	(Original Budget or Bid)/Total Final Billings	
	% profits	(Original Budget or Bid Profit)/Actual Profit	
Schedule Performance • Project Completion	Original Planned / Actual Schedule	Original # of Project Days / Actual Project Days	
Quality of Work & Management • Workmanship • Disputes • Finalizing Construction	Number of Punch List Items	Actual # of Items on the Architect's punch list at Substantial Completion	
	Amount of Dispute Items	Total $ Value of Claims at Project End, if any.	
	# days, Substantial to Final Completion	Actual # of Project Days from Substantial Completion to Final Payment Authorized	
Minority Participation • Met Project Goals	% Participation	$ Value of Minority Contracts/Total Value of the Contract Work	
Satisfaction of Project Participants • Owner Satisfaction • Contractor Team Satisfaction • Community Satisfaction	Letter of Recommendation, Repeat work	Did the Owner provide a letter of recommendation or did the Owner give the Contractor repeat work?	Yes or No
	Peer Rating/Advancement in Company	Did the Contractor's project manager receive a favorable internal review and/or advancement within the Company?	Yes or No
	Complaints from Project Neighbors	Did project neighbors make any formal written complaints about the construction work or project?	Yes or No
Project Safety • Safety Performance	# Lost time or Recordable time Accidents	Actual number, regardless of length of time.	
	$ Value of Accident	Total $'s paid out by the Contractor or the Contractor's insurance carrier for accident claims	

Figure 12 Picture of Project Output Data Collection Form

The actual Project Output Data Collection form given to contractors is presented in Figure 12above, and the Project Input Data Collection form is presented in Figure 13 on page **Error! Bookmark not defined.** below.

3.3.3 Output Metric Definition

The next step in this project was to focus on defining the input and output metrics in a way that could be obtained, would make sense within the context, and could easily be calculated.

The three most common measures of construction project performance are: Cost, Time and Quality. As discussed above, the financial and schedule measures, cost control, profit and schedule control would be proportional figures, a ratio of the planned and actual performance. Both cost and schedule control are calculated as Planned/Actual, and the Profit is calculated as Actual/Planned. The reason for these differences is probably obvious, but for the sake of discussion, the schedule and cost control metrics are measures of control, meaning that the contractor's ability to cut costs and beat the schedule are positive performance characteristics. Since it is important for an output to increase in value relative to the desired outcome, our metrics had to increase with the decrease in cost and time performance characteristics, therefore we chose cost and schedule control, calculated as the Planned/Actual performance.

Profit, on the other hand, was calculated as Actual/Planned because the contractor's ability to increase profit was positively correlated with performance.

"Quality of Work" and "Project Management" performance metrics had to reflect the contractor's work performance in some objective manner.[32] Volpe [211] defines a Punch List as a "list of uncompleted or corrective items of work to be done to complete the contract. These lists are prepared by the architect after an inspection of the project at substantial completion.[33]" One measure of the contractor's performance is the number of items on the architect's Punch List. However, since the number of punch list items would increase with the size of a project, the metric would eventually have to be made relative to

[32] Note the discussion in Appendix F regarding the CII metrics for quality of performance.
[33] Substantial completion is "the point of completion at which the owner may beneficially occupy the project" or in other words, when the project is completed and ready for its intended use [211].

project square footage. For the data collection instrument, the data that was needed was fairly straightforward: Number of Punch List Items at time of Substantial Completion. Also, our Expert Panel chose: Total dollar value of Disputes or Claims at the Project End, if any; and, the Number of days from Substantial Completion to Final Payment as measures of project quality. The dollar value of disputes or claims is probably an obvious measure of quality of management, or at least of the relationship between the project parties; if there are a lot of claims or large claims and disputed items, the relationship between the parties is poor. Alternatively, if the parties are able to work out their differences during the project and settle all disputes and claims, then the relationship between the parties is very likely to be working fairly well.

Finally, the contractor's efforts to close out the contract and finalize all work were considered a positive measure of performance. None of the parties in a construction project wants the project completion to drag out for long periods of time. Contractors lose money because they have to manage the completion process and that takes away from time their project manager could be devoting to profitable ventures; architects have to spend their time, some times un-reimbursed, to inspect and re-inspect the contractor's work; and owners have to put up with a less than complete building. None of these are popular or positive prospects. Therefore, the amount of time the contractor spends from the substantial completion to the point in time where the punch list is competed and the final payment[34] is made is an important measure.

[34] Final payment is most likely the release of retainage, the money withheld from progress payments to insure the work is actually completed to the Owner's and Architect's satisfaction.

In addition to the cost, profit, schedule, and quality metrics, it was important to obtain other information about the project, such as the type of project and its size in square feet.[35] For the most part, it was felt that these data would be less sensitive than the financial (in particular Profit) data requested, with the possible exception of "Claims" because no business likes to be thought of as "Claim Oriented." But, that data is public information on these Public Projects, and not entirely the fault of the Contractor. Nevertheless, the "Claims" question was generally ignored except to state: "None" in most cases.

Minority Participation, which was identified by all Stakeholder Groups in the Expert Panel as being an important measure of project success, was asked as a proportion of the total contract value. This is also the way it is generally required under most public contracts,[36] however, it must be pointed out that these rules are constantly changing with court rulings on both the State and Federal levels.

The Satisfaction of the project participants was identified as a project success measure yet how "satisfaction" should be measured was not precisely defined by the Expert Panel members. A subjective rating scale measure could be used; however, where possible it was thought that objective measures should be obtained. The Expert Panel

[35] Here size in square feet is only concerned with the square footage of the building itself, or the portion of the building, in the case of major remodel projects, that is actually being worked on. A lot of projects, especially school projects, are built on large sites. This fact also makes it difficult to compare the cost per square foot of projects since neither contractors nor owners precisely break out those costs from an overall lump sum or GMP. It may be possible, especially with GMP's to break out the building costs, but then some kind of assumption would have to be made regarding the proportion of overhead and profit was associated with the site and building work.

[36] In a succession of US Supreme Court cases beginning with J.A. Crosson v. Richmond, and concluding recently with Adarand v. Minetta the US Supreme Court has struck down most race based minority set aside or preference programs. Oregon has adopted a "Good Faith Effort" standard under several Agency Administrative Rules (or OAR's) and the Model Contract Rules promulgated by the Department of Justice.

suggested that project satisfaction could be obtained by noting whether or not the contractor received a letter of recommendation or commendation from the project owner, whether or not the project received any architectural awards and if the project team members received commendation or promotion within their organizations. Finally, the Panel suggested a measure relating to the community or project neighbors; whether or not any complaints were received by the project neighbors.

We decided that that these measures could be measured satisfactorily with Yes/No measures. (Rating on a 1-5 or 1-10 scale would be difficult and possibly embarrassing to the project team.) Furthermore, rating an owner's letter of recommendation or commendation would be highly subjective and probably would tend to be very high (all tens for example, because what possible reason could be given for a low rated letter of recommendation?). Architectural and Engineering Awards were rejected because very few projects actually receive awards, and some awards are substantially more prestigious than others. Also, any award may or may not have anything to do with the contractor's performance – architectural design awards, for example, are given for the architect's performance, not the contractor's. The point of this research is to evaluate the different outcomes of project performance based on PDS, and a design award may not have any relationship to the PDS used.

"Project Safety" was the final project performance measure suggested by the Expert Panel. However, the contractor panel members pointed out that various contractors may measure safety performance in different ways. The most common way of measuring "Safety" is in "Lost Time Accidents." But since "Lost Time Accidents" can be "gamed" in order to hide accidents on the job, it may not be a reliable indicator of project safety. Another way to measure Safety is in "Recordable Incidents" as required by Oregon Occupational Safety and Health Administration (OSHA). Recordable incidents include all accidents not considered as "first aid" and generally requiring medical attention. The records required by OSHA distinguish between accidents that cause an employee to lose work entirely from those where the employee returns for work in a "modified" or different capacity. Another way of measuring safety performance is in total dollar value of accident liability. However, as it turned out, contractors would not release that information, and the owner simply did not require it. While safety information is required by Oregon OSHA, Oregon OSHA is not disposed to release that information to the public, much in the same way the IRS is not disposed to release individual tax returns.

3.3.4 Input Metric Definition

Construction Project Inputs and Company Profile

Metric	Measure	How to Calculate	Response
Contractor Capacity This is a measure of the Contractors' project management capabilities • Team Experience	# Years Experience	Project Manager's years of Construction Experience at the time of the project? This is meant to be management experience, and includes years as a Field Engineer, Project Engineer, Scheduling Engineer, Superintendent, Project Manager and/or Project or Company Executive	
Project/System Constraints This is a measure of the obstacles to the Contractors performance in terms of quality of documents, difficulty finding trained labor, physical constraints of the site and the available time and budget expectations of the owner. • Design Completeness • Design Quality • Labor Market & Quality • Adequate Access to Site • Adequate Time allowed by Owner • Adequate Budget allowed by Owner	% Complete @ Bid or GMP	Your estimate of % complete of the plans at the time of the Bid or GMP	
	# of RFI's (Requests for Information)	Actual # of RFI's issued by the Contractor?	
	Labor Union Employment Level	Your estimate, based on "normal" labor market conditions and your ability to attract experienced, quality tradesmen for the job: on a scale of 1-5, with 1 being: No problem and 5 being: very difficult to attract.	Scale 1-5
	Rating of Access from Difficult to Easy	Your estimate on a scale of 1-5, of how difficult the project site was to access, amount of space available for storage and parking: Easy Access = 1; Average; Difficult Access = 3; Extremely Difficult Access = 5.	Scale 1-5
	Owner's project time expectations relative to Industry Standard for size & type work	Your estimate on a scale of 1-5, of the Owner's expectations about the amount of time allowed to perform the work: easy to achieve = 1, about average for the work = 3, very aggressive schedule = 5	Scale 1-5
	Owner's budget relative to Means Standard for size & type work	Your estimate of the Owner's budget expectations on a scale of 1-5: Unrealistic and Inadequate for the work requested = 1; A bit low, but not unrealistic = 2; Adequate to do the work and cover some contingencies = 3; more than adequate = 4, budget never a consideration/concern = 5	Scale 1-5
Owner's Project Team This is a measure of how prepared the Owner's team was to assist the Contractor in the performance of the project • Owner's Ability to define project • Experience of Owner's Team • Responsiveness to $ & Time issues	# of Architect Revisions	Actual # of revision drawings issued by the Architect to correct design errors, flaws or unexpected conditions in the work.	
	Years Experience & Training	Your estimate of the Owner/Architect's team level of experience in Construction of this type on a scale of 1-5: Low = 1, Average = 3 or High = 5?	Scale 1-5
	Average # days to respond to issues	Your estimate of Owner/Architect's response to time and money issues on a scale of 1-5: Slow to respond=1; about average for this type of job=3; very responsive5.	Scale 1-5

Figure 13 Picture of Project Input Data Collection Sheet

Two different Project Input Data sheets were given to Contractors at the beginning of the data collection phase this research. Figure 13 above is the project input data collection sheet, and the other data collection survey instrument was used to describe the overall company resources: personnel, bonding capacity, and total volume of work.

The key player in any project is the project manager whose experience, background, and training as well as his or her ability to anticipate problems and solve them in a timely manner is critical to project success. The Expert Panel felt that one way to measure this resource would be the number of years of professional construction management experience.

Other inputs were described as: "obstacles to the contractor's performance" and included: Design Completeness, Design Quality, Labor Market, Access to the work, Amount of time allowed under the Contract and Adequate budget for the work.

The intent was to characterize the amount of information that was available to the contractor at the time of the bid or formation of the guaranteed maximum price (GMP) – noting that the amount of information would fall somewhere between no information and perfect information. Design completeness is one way to evaluate the amount of information and could be measured as the percent complete of plans and specifications at the time of the bid or GMP. On a Design-Bid-Build project, it is generally assumed that the plans are 100% complete in spite of the fact that is almost never the case, and of course even 100% complete plans and specifications fall short of what would be considered "perfect information." However, unless otherwise noted by the contractor or architect or other data source, 100% complete plans and specifications would be assumed on all projects.[37] Architects differ in how they rank levels of design and at what precise percentage complete each level of design actually achieves. In general, the levels are: planning, conceptual design, design development, schematic design, and working drawings or final design. Recall from Table 4 planning and conceptual design are on the order of 10 to 40% of the final completed drawings, schematic design ranges from 30% to 70%; design

[37] This would be true for both CM/GC and DBB projects, although it is normally the case that CM/GC projects are authorized as "fast track" the uses less than complete plans to start the work. Since 100% is the maximum number it would be conservative relative to the model, to assume 100% unless otherwise noted, because this would neither reward nor substantially penalize a project's efficiency score.

development ranges from 60 to 90% complete but usually is on the order of 75% complete, and working drawings range from 90% to 100% range.

Another way to evaluate "information" is to look at the quality of finished plans and specifications – this can be accomplished by obtaining the number or Requests for Information (RFI's) or questions regarding the work from the contractor, and number of architects' revisions or Proposal Requests instigated by the architect to clear up confusion in the plans and specifications.

3.4 Data Collection Phase

The data collection phase began in the summer of 1999 with the issuing of the data collection survey instrument.

3.4.1 Contractors

Based on our experience in the construction industry, we expected that contractors would be the best source of data for this research. A contractor's profit on competitive lump sum bid projects, for example, would never be known by the owner or architect on a project. Items like the total profit realized as a proportion of the amount initially anticipated at bid time could only come from the contractor themselves. In addition, items like the number of RFI's (Requests for Information), the Number of Punch List Items, and Schedule performance would be more readily accessible to the contractor, who is more likely to track of these items in his management information system.

3.4.2 Making Use of the Expert Panel Members

The strategy adopted early on was to solicit the support of the contractor's management personnel to serve as expert panel members. It was expected that if they served on the Expert Panel and helped to arrive at the metrics measured in the study, they would be more likely to provide the data that they determined was important to measure. In addition, the strategy was to gain the support of the largest and most influential general contractors in the state and those with the most experience in both CM/GC and Design-Bid-Build contracting methods: Vice Presidents, Chief Estimator's and Senior Project Managers from Hoffman Construction Company, J.E. Dunn, Andersen Construction, Lease Crutcher Lewis, and Baugh Construction Oregon, the five firms with the majority of early CM/GC experience and three (Andersen, Dunn and Hoffman) of the oldest general contractors headquartered and doing business in Oregon. These five firms performed approximately $1.8 billion of the $5 billion in construction documented in this research – one contractor, Hoffman accounted for $1.1 billion of this figure; therefore, in order to have a credible study, their participation was considered key.

Unfortunately, in spite of our successful strategy to recruit and capitalize on contractor Expert Panel members, the acquisition of data from contractors did not go as swiftly as planned, nor did it yield the amount of data that we had hoped. The five initial contractors provided us with approximately 180 projects, but these were heavily skewed toward CM/GC projects with only about 30% being DBB. As one Expert Panel member told me, his company's main concern was making sure that this research did nothing to diminish the use of alternative contracting methods and specifically CM/GC; therefore, they would only provide us information on CM/GC projects and only those that were considered superior projects.

The data collection from contractors started in the summer of 1999 and was completed in February 2002 with a total of approximately 180 projects; however, not all projects were useable in our model. Some did not contain enough of the required data, while others were not "public projects;" but rather were private CM/GC jobs.

3.4.3 Non-Expert Panel Member Contractors

The Expert Panel member companies, while being among the largest public construction contractors, certainly were not the only companies that perform a substantial amount of public building projects in Oregon. One of the larger sectors in public buildings is the public school sector which had been dominated by a number of smaller general contractors, principally Robinson Construction Company headquartered in Hillsboro, Oregon. However, we were less successful in obtaining data from non-Expert Panel member companies. For example, Robinson's chief estimator agreed to provide data for the research, but left the company prior to working on that effort. Subsequently, the Vice President that oversees construction promised to have someone work on the data collection but never found the time (nevertheless we did obtain several Robinson Construction projects through other sources, principally owners and the DJC). Yet another contractor, Emerick Construction, simply refused to provide any information or data for our study because the president of the company felt the study was biased against CM/GC procurements.[38]

We were successful in obtaining information from a number of non-Expert Panel contractors, either directly or through owners. Kirby Naglehout, headquartered in Bend in central Oregon provided data on several projects as did several central Willamette Valley contractors including Pence-Kelly Construction in Salem, Ramsay Gerding Construction Company[39] in Corvallis and Wildish Construction in Eugene. Some of this project data was incomplete, but by combining it with project data obtained from owners, architects, and the *Seattle Daily Journal of Commerce* (DJC), we obtained enough project information to be able to use many of these projects in the model.

3.4.4 Contractor Websites

The World Wide Web has become an amazing source of information of all types including information on construction projects. Nearly every one of the contractors in our database of projects has a website with past project information. This information was typically limited to data on project type, size, often times the final project cost, architect, and owner. This information could then be cross checked with architect's and owner's websites for accuracy and completeness. Using all of these sources together, combined with data from the *Daily Journal of Commerce*, it was often possible to piece together enough information on a project that it could be used in the model.

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[38] Some of the early data collected by the researcher for the dissertation proposal that simply documented the growth in CM/GC projects in Oregon and the distribution of contractor's performing that work was introduced in a hearing before the Oregon Legislature considering a rewrite of bidding requirements and again in a Marion County Court hearing by a group of contractors opposing a CM/GC award to Emerick.

[39] Now, T. Gerding Construction.

3.4.5 Owners

There are literally hundreds of public owners in Oregon; however, the vast majority of public building projects that fit our model criteria are constructed by a surprisingly small number of government entities. These include: Oregon University System (and its seven member universities), Portland and Clackamas Community Colleges, the Cities of Portland, Salem, Eugene, Beaverton, Tigard and Gresham, school districts in these same cities, The Oregon Department of Administrative Services, The Oregon Department of Corrections, The Oregon Military Department, and the Port of Portland. While these owners don't track all of the data that we would like to have obtained, they do track and keep information on costs, change orders, schedule, punch lists, claims, and RFI's in their archives.[40]

The Oregon University System (OUS) was the most fertile and (generally speaking) most open to allowing access to their files of any groups that were approached. Portland State University (PSU), Oregon State University (OSU), the University of Oregon (U of O) and Western Oregon University (WOU) granted complete and uncensored access to their construction project files. The U of O even supplied a summer intern student to assist in finding and pulling project files in their vast archive. Only Oregon Health Science University (OHSU) initially refused access to their project records, claiming that they were exempt from public disclosure laws under current statutes. OHSU's corporate counsel

[40] The final change order on a project was the single best source of data because it typically would list the original contract amount, original schedule requirements, and all changes to those requirements. As noted earlier, this is standard on public projects in Oregon, because a project manager and state agency must have a legal contract amendment in order to pay a contractor more than the original bid amount or otherwise risk severe penalties under the law.

determined that they were in fact not exempt and did provide some information on a few of their projects.

Each of the major universities, PSU, OSU and the U of O, provided this study with between ten and twenty projects each. WOU, a smaller campus located in Monmouth, Oregon contributed another five. We contacted Southern Oregon University (SOU), Eastern Oregon University (EOU), and Oregon Institute of Technology (OIT), but only SOU had recently built a project that met our research guidelines, and it was under construction when we contacted them. OIT and EOU had built sizeable projects in the past, but none in the most recent 20 years.

The Cities of Portland, Salem, Eugene and Beaverton all contributed multiple projects data for this study, as did Portland Community College, Portland and Beaverton School Districts, the State of Oregon Departments of Corrections, Administrative Services and the Military.

The data obtained from project owners could generally be retrieved from a small number of project files. Most owners keep files on the original project contract, change orders, correspondence, and close-out. The original contract file normally documents such data as the project description (including size in square feet), original contract schedule, and cost. The Change Order file will give the final contract amount.[41] The correspondence file often either contained or referenced the number of RFI's on a project; alternatively, many owners keep a separate RFI log file as well as a proposed change order file. The

[41] All public contracts in Oregon authorize the expenditure of public funds and limits that amount to the amount of the contract as amended by change order. In order to pay a contractor more than the original contract price a proper change order or contract amendment must be executed (see WE Group v. State of Oregon.)

project close-out file usually documents the date of substantial completion, final payment and may contain the architect's punch lists; some of these data may be in their own separate files or found in payment or correspondence files. On the CM/GC projects, some profit information may be found in the owner's files if there was a project audit performed.

Few owners actually maintained websites that were of much help to this work. One exception was PSU, whose facilities department actually has plans and descriptions of every campus building on their website. These were extremely helpful for gathering data on floor areas.

The owners also contributed the ORS 279.103 post hoc reports on CM/GC projects discussed more fully in Appendix F. These reports were required by the Oregon Legislature following the 1997 session as discussed in Section 2.7.2. As noted earlier, these reports vary in completeness from agency to agency, but regardless of the quality of the particular agency reports, they all provided the minimum amount of project data (with the possible exception of the COCC report which required other information sources including the DJC, the world wide web, and contractor input) required for the projects to be used in the model.

It is interesting to note that the Oregon University System and OHSU are exempt from ORS 279.103, and project personnel at OHSU, OSU, WOU, U of O and PSU do not have to prepare these post hoc Evaluation Reports, and so far as we were able to determine they have not prepared them.

3.4.6 Architects

After finding a number of projects on contractor's websites, the next step taken was to search the major architecture firm's websites. This resulted in the acquisition of several projects for a number of firms. Unfortunately, architects generally don't track the type of information that was necessary for this study, so the architect's website project information became both a back-up for confirmation and a jumping off point for acquiring data.

3.4.7 Seattle Daily Journal of Commerce On-line Database

On August 15th, 2002 the *Seattle Daily Journal of Commerce* (DJC) granted us unlimited and free access to their on-line database of projects which dated back to 1994 and contained more than two hundred Oregon public projects. A sample of the information contained in the DJC reports is presented in Figure 14.

Construction of the Eugene Public Library
Eugene, OR, #2001-1001
Bids due: 4 pm Oct 11, 2000 Extended from Oct. 4. Subs due 11:30 am, Oct. 5.
1-3 addenda
Estimated cost: $22.7 million
Owner: City of Eugene Public Works Dept, Facility Management Div, 210 Cheshire Ave, Eugene, OR 97401, 541-682-2689
Printer: Central Print & Blueprint, 47 W 5th Ave., Eugene, OR 97401, 541-342-3624, fax 541-345-3286
Submittal Docs: $200 non-refundable from Owner
Bids to: Owner
Invitation #: 2001-1001
DJC Ref #: 0008290013
Bond: 10%
Notes: The bidder must be registered with the Construction Contractors Board. Sub-bidders and suppliers may purchase documents from the printer.
Pre-Bid: Conference 10 am, Sept. 13 at St. Mary's East Main Hall, 1062 Charnelton St., Eugene, Ore.
Scope: City Job No. 50160: Construct a 5-level, 160,000 sf library and office building, consisting of 1-level below grade parking, 3 floors of library, and 1 floor of general office space. Project includes site work and public improvements.
Apparent Low Bidders 7 bid(s) received

John Hyland Construction, Eugene, OR jensmith@jhconst.com:	26,525,100
Robinson Construction Co., Hillsboro, OR	26,705,800
JE Dunn Construction, Portland, OR	27,004,800

Figure 14: Text from DJC database

Many of the DJC reports contained valuable information for our study, including the name of the owner and architect, the date the project was let, the type of the project (CM/GC or DBB), the scope of the work (typically including the square footage and type of project – in the above case a new library), and in most cases the original bid price, award price (if it differed from the lowest bid) and sometimes the initial GMP, if known. On several projects the performance period was given as well as information on project contacts such as phone numbers or email addresses of the owner, Architect or Contractor.

3.5 Data Available for the Analysis

Through all of the different sources we were able to identify over 500 public projects, 407 of which generally fit the size and complexity criteria for this research. We did include a few projects that were smaller than we had originally wanted to use, however it was determined that they were all sufficiently complex enough to include in the analysis. Of the 407 projects, we obtained some cost information on 367 projects, ranging in cost[42] from a $175,591 (CM/GC) fire station project to a $189,859,282 (CM/GC) airport expansion project; totaling $5,050,962,407 of public construction between 1986 and 2002. We were not able to get final project costs on a large number of the projects we obtained from the DJC website, and some of the projects we obtained from architect's and contractor's websites did not tell us what PDS was used. A summary of the 407 projects by PDS is contained in Table 8:

[42] These costs are adjusted to 2001 using Engineering News Record's Construction Cost Index obtained from their website at: http://enr.construction.com/features/conEco/costIndexes/constIndexHist.asp .

Project Delivery System	Number	Smallest	Largest	Number with Unknown Financial Information
CM/GC	136	$175,591 1,400 SF	$189,859,282 1,000,000 SF	8 with no $ data 17 missing some $ data
Design-Bid-Build	191	$663,325 4,600 SF	$112,497,017 569,000 SF	2 with no $ data 89 missing some $ data
Unknown	80	$223,166 11,300 SF	$35,211,963 $270,000 SF	2 with no $ data 78 missing some $ data
Total	**407**			

Table 8: Summary of Oregon database Projects by PDS

Note that the final model included 215 projects, 111 of the 136 CM/GC jobs and 104 of the 191 DBB projects. We obtained a higher proportion of the CM/GC projects principally because the information on a large number of the DBB projects from the period of the 1980's through 1995 no longer exists, as noted earlier.

A total of 71 different Construction Contractors were represented[43] in the Oregon database obtained. The top six Contractors by total sales are listed in the following table:

		CMGC		DBB		
	Contractor	**No.**	**Total $**	**No.**	**Total $**	**Total**
1	Hoffman Construction	42	1,490,850,578.18	3	134,662,229.86	1,625,512,808.04
2	Dunn / Drake Construction	10	281,124,745.46	15	176,474,011.61	457,598,757.07
3	Baugh Construction Oregon	18	334,845,361.45	1	883,949.85	335,729,311.30
4	Robinson Construction	6	37,947,953.39	14	122,554,258.92	160,502,212.32
5	Kirby Nagelhout	3	21,421,521.39	10	106,540,769.06	127,962,290.45
6	Lease Crutcher Lewis	11	124,723,971.16	0	-	124,723,971.16

Table 9: Top five contractors by total sales in the Oregon database

A total of seventy different architecture firms[44] are represented in the Oregon database, and the ten Architecture firms with the greatest number of projects in our study are shown in the table below:

[43] This number includes two Joint Ventures as separate companies from their parents.

Architect	Unknown	CM/GC	DBB	Total
1 Dull Olsen Weekes	0	13	48	61
2 ZGF	4	9	5	18
3 BOOR/A	1	1	12	14
4 SRG Partnership	2	4	8	14
5 Malhum Architects	1	7	5	13
6 gLAs Architects	2	3	7	12
7 YGH	1	7	3	11
8 Arbuckle Costic	2	1	7	10
9 Soderstrom	2	2	6	10
10 Barber Barrett Turner	1	0	7	8

Table 10: Architects in Oregon database

The table of architects shows that there were 106 projects where the project architect was not known, and this was the largest single groups of projects in the database. The firm of Dull Olsen Weekes and Associates (DOWA) provided the study with the largest number of projects. DOWA, as they are known, specializes in school construction and nearly all of the 61 DOWA projects are elementary, middle and high schools in Oregon.

3.6 Adjusting the Data for the Model

In this section, we discuss how we dealt with the data and prepared for the actual analysis.

[44] Note that some firms have changed names over the years; we have attempted to count a firm only once if it added or lost partners along the way. However, Joint Venture firms were counted separately from their parent organizations consistent with our treatment of contractors.

3.6.1 Transferring the Data and Data Reduction

The process of taking the data from the Access Database and running the model was not a trivial procedure. The first step was to take all of the data and copy it into an Excel spreadsheet; this spreadsheet was given the name "Base Data." Two data transformations were performed on the Base Data sheet: first, a Look-up operation was performed to inflate the "final billing" amount to end of the year 2001 base dollars using construction cost index figures obtained from the ENR website. Secondly, the cost control metric was recalculated as a cross check to make sure no calculation errors had taken place. After these two operations were complete, the Base Data Sheet was generally never touched again, except to reference.

The next step was to copy the main "Base Data" spreadsheet to a new spreadsheet named 1st Reduction. The data was transferred from the Base Data sheet where some of the numerical data in the Access Database transferred over as text. At this point we corrected all text errors and architect and contractor name inconsistencies.[45] All data transferred from the Base Data Sheet to the 1st Reduction Sheet were copied and pasted using the "Paste Special" function in Excel that allows you to transfer over only the "values" and exclude formatting and functions.

Once the 1st Reduction sheet work was completed, it was copied into a 2nd Reduction Sheet. This sheet was used primarily to perform pivot tables in order to obtain the information shown in the tables in Section 3.5 above.

---

[45] In some cases architecture firm "XYZ" may have included the word "Architect" or "Architect's & Planners." Names for contractors likewise may have included the word, "Contractors," "Builders," or "Construction Company."

At this point another spreadsheet was opened and named 3rd Reduction. This is the first point where we began deleting projects from the data in order to perform the analysis. The process began with the sorting of the project data in ascending order by: Project Size in Square Footage, Final Project Cost and Original Bid/GMP. Thirty projects in the spreadsheet contained no information on any of these measures and therefore could not be analyzed in the model. The next ninety-seven projects had no information about either Project Size in Square Footage or Final Project Cost and were therefore eliminated at this point, and eight additional projects contained no information on both final and original costs and the schedule control metric necessitating their elimination from the spreadsheet. Finally, fifty-nine of the remaining projects had no information on the two principal output metrics of cost and schedule control and were therefore eliminated. This left a total of 215 projects in the spreadsheet for analysis; of these, 111 were known to be CM/GC and 104 were known to be Design-Bid-Build projects.

The final step is to prepare the "DATA" spreadsheet to be used in the analysis. This requires transforming the information contained in the 3rd Reduction sheet to fit the input and output model described below.

3.6.2 Model Inputs

The inputs for the model include two input metrics intended to reflect the amount of information the contractor would have at the time of preparing his price, which are % Complete of Plans and Specifications and Total SF/(RFI + AP) issued during the course of the work. The first metric is rather straightforward; it is simply a measure of how complete the plans and specifications are. The second measure is intended to try and measure the quality of the plans and specifications. It is assumed that a poorer quality set of plans will produce a larger number of RFI's (for clarification sake) than a higher quality set of plans, and also would require more Architects' Proposal (AP) requests to deal with deficiencies. While we stand by this assumption, we acknowledge that the issuance of RFI's can become something of a game for contractors, design professionals, and owners. RFI's can be used in a number of ways to document problems the builders encounter in the plans and specifications. In addition, on several projects performed before 1990, we found that several Contractors did not use specific "RFI" forms; instead they used project correspondence, often tracked by "serial numbers" to document problems and change order requests.

Since the assumption made earlier was that number of (RFI + AP)'s increases as the quality of the plans and specifications decrease, we needed to find a way to express this data so that it conforms to the model input requirements that a large number should indicate a large resource with which to produce outputs. A small number reflects a limited resource that inhibits the production of outputs. In addition, we observed that very large projects would naturally have more RFI's than very small projects, and that a large project would not be as constrained as small projects with the same number of RFI's. In order to reflect this relative resource and constraint, we divide project size in square footage by the sum of the RFI's and AP's.

3.6.3 Missing Data in Model Inputs

Missing Data in Model Inputs had to be dealt with at this stage because several projects lacked RFI and AP data. Since that would result in a zero resource on the input side of the model (which would result in an infinite output/input ratio), we would have to adjust that data in the most reasonable way possible without harming the rest of the project's efficiency performance measurement. The most reasonable way to do this, we concluded, was to assume that every project would have at least one RFI issued during the course of the job, which seems a reasonable assumption, given that every project that did include data on RFI's and AP's had at least one RFI (in fact the lowest number was 9). In doing so, we are assuming a near perfect set of plans for the level of completeness estimated by the project team. This would insure also that the "quality" input would not be used by any of the DMU's and it was not.

For the other input, % complete of plans and specifications, 100% complete was used as the default if data was missing.

3.6.4 Model Inputs That Were Not Used in the Model

The Expert Panel work, described in Section 3.2.1, resulted in six measures for model inputs that were not used in the initial DEA model. These were scaled subjective ratings (1-5) that attempted to evaluate the difficulty of the "construction environment" during the course of the project. These included: skilled labor recruitment, access to the work, owner's schedule expectations, owner's budget expectations, owner team's level of experience, and architect's timeliness of response to issues as they occurred. Another metric not initially used was the number of years of experience of the contractor's project manager.

These data were obtained from the contractors with relative consistency; however, remarkably few architects or owners ranked their projects on these metrics. This was probably due to the fact that few owners would know precisely what the market conditions for labor employment were actually like and would only be able to guess at the project manager's experience. It's likely that the owner would think his budget and schedule were adequate regardless of what the contractor thought. These missing data tended to skew the results with an enormous amount of missing data.

3.6.5 Model Outputs

The basic model outputs were consistently agreed upon by all of the stakeholders in the Expert Panel: Financial Performance (both budget and profit), Schedule Performance, Quality of the Work (workmanship, disputes, and finalizing construction), Minority Participation, Project Safety, and Satisfaction of the Project Participants. They are similar to the measures used by Sanvido, Konchar and the CII [75, 76, 126, 182, 183], although modified for the DEA model.

Some, like Ruskin [176], have proposed an "earned value" metric; however, while this is a recognized tool for tracking the project performance, it provides no advantage over the metrics used here for post project performance derived by the Expert Panel or as used by the CII supported studies (cited above.)

Note again that for the DEA model, outputs are considered "goods" whereas inputs can be considered "bads" in the sense that increasing these will either make the efficiency score increase (good) or decrease (bad). Therefore, the input and output metrics had to be mathematically arranged to reflect this arrangement. For example, the metric used in the model for project budget and schedule performance are "cost control" and "schedule control" instead of the more common reciprocals: cost and schedule over-run. This is because if we were to use cost or schedule over-run as an output, the more the cost and schedule exceeded the contract cost and schedule requirements, the better. Obviously, this is counter to the goals of a project (to reward the project for being more over budget)! Therefore, the metric used for budget performance: cost control, is equal to: (Original Contract Cost)/(Actual Amount Paid). A similar formulation is made for schedule performance or control. Alternatively, profit is the reciprocal, that is, the more profit the better, so the profit metric is equal to: (Actual Profit)/(Contract or Bid Profit.)

3.7 Output Metric Two-dimensional Plot

One example that is commonly used to explain the DEA and frontier analysis generally is to plot the results in a two dimensional scatter plot. This can easily be done in cases where there are either no inputs or one single input for the DMUs and two outputs as shown in Figure 15.

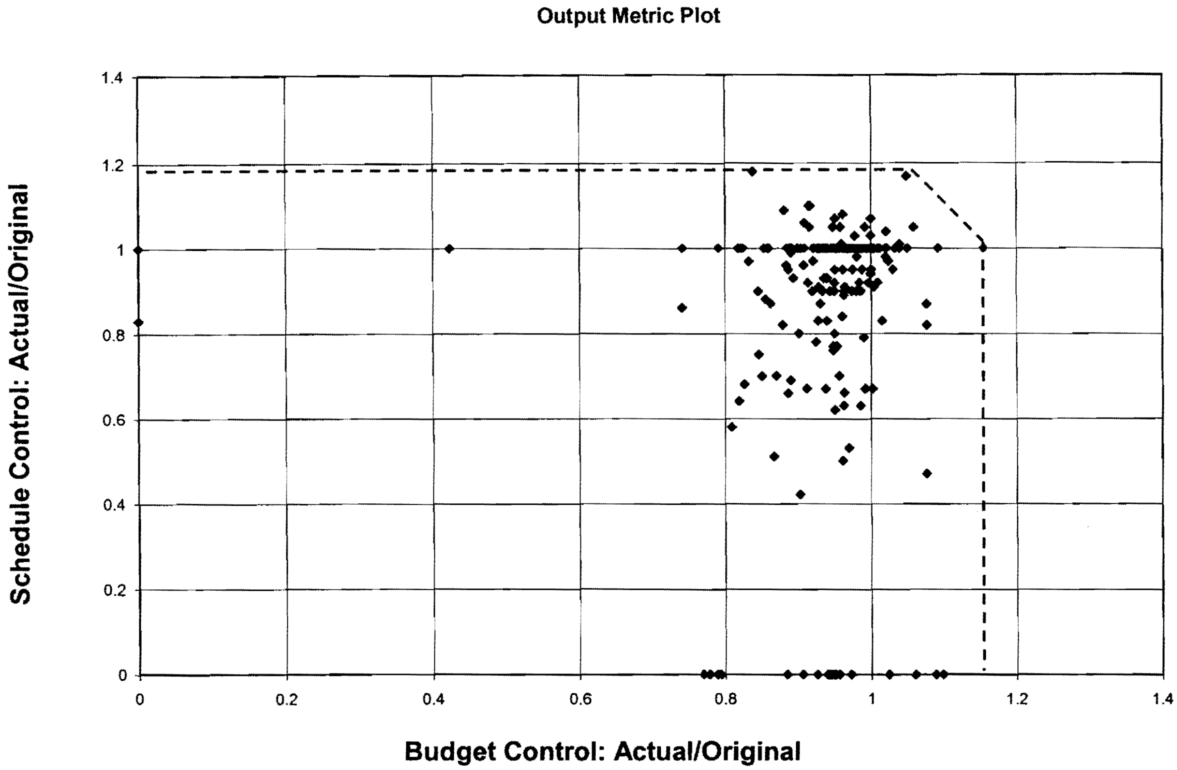


Figure 15: Two Dimensional Scatter Plot of the Output Metrics from the Oregon Database

If there were no inputs, and the only outputs were schedule control and budget control, then the envelopment of this data, shown as a dashed line above, would give us an efficiency frontier, and the technical efficiencies of the projects would be calculated as the relative distance from the origin to that frontier. From the plot, it appears that the minimum efficiency would be in the range of 0.70 or 70%. Again, however, the important thing to note is that the data is not broadly distributed, but instead it is rather tightly grouped around the 1.0, 1.0 intersection. In fact, only just slightly more than 13% (29/218) of the projects with non-zero data points fall outside of plus or minus 20% of the 1.0 measure in either direction. If DEA had been run using this data, it appears that just three projects would form the efficiency frontier, but the model used in this research does include inputs and additional outputs to consider.

4 Data Analysis

This chapter presents the data analysis used to answer the first three research questions regarding project performance, project efficiency and benchmarking. The objective in this section is to determine, through quantitative methods, if the public policy that allows public agencies to select construction contractors on the basis of past performance instead of lowest responsible bid should be continued and to determine if there are "best practice" applications of the two PDS's.

The DEA model was analyzed using the EMS software developed by Holger Scheel (Version 1.3 2000-08-15). This program uses an Excel spreadsheet to store the input and output data, which greatly facilitated the data processing.

4.1 Project Performance Statistical Analyses

Project performance is analyzed using the principal output statistics cost and schedule control. Here we test the hypotheses:

> H_{A1}: Negotiated Procurement, Construction Manager/General Contractor (CM/GC) method of Project Delivery System (PDS) results in projects that outperform the traditional Design-Bid-Build (DBB) PDS method on cost and schedule control metrics.
>
> H_{01}: There is no significant difference between CM/GC and DBB projects with respect to cost and schedule control metrics.

Figure 16 is a single frequency histogram of the output metric Budget Performance, which we defined above as the total final cost divided by the initial bid or contract guaranteed maximum price. Note the average Budget Performance is 0.947, with a standard deviation of 0.07. The figure indicates that the data is generally well distributed with one outlier at the extreme left-hand side of the figure.

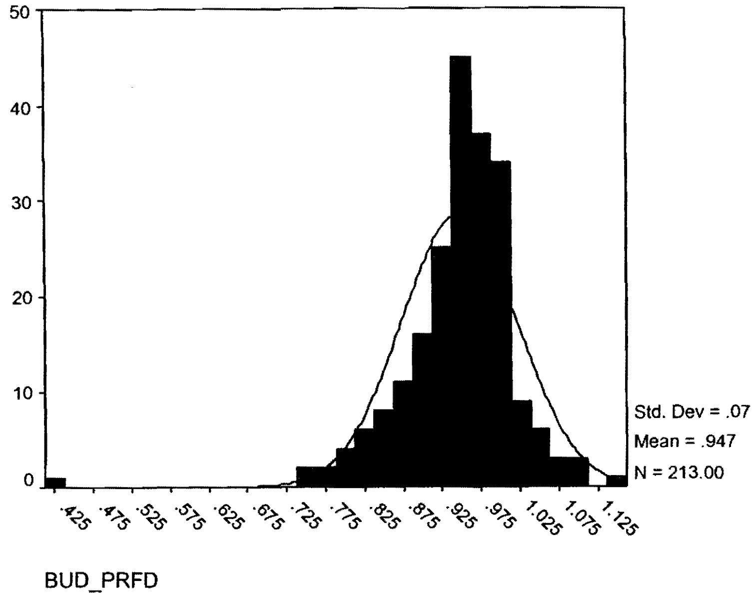


Figure 16: Budget Performance Metric Histogram

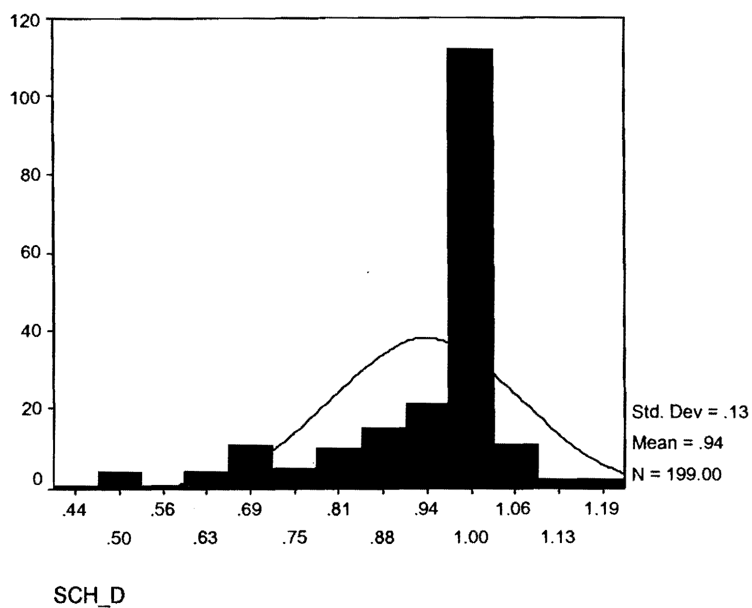


Figure 17: Schedule Performance Metric Histogram

Figure 17 is a single frequency histogram of the Schedule Performance metric, which indicates a much broader distribution than the Budget Performance metric. This stands to reason because time is a more available resource than money in most situations, and exceeding planned performance time is more likely and less costly than exceeding the project financial resources. It's far more likely to allow a project to run longer by 100% of the original schedule, resulting in a Schedule Performance Metric of 0.50, than increase by double the cost. An increase in total cost of double would in fact only occur in projects that undergo a "Cardinal Change[46]" and therefore, by definition, the original contract value is irrelevant because it does not reflect the intent of the contracting parties.

4.1.1 Population Independence

The principle purpose of this research was to determine if the different project delivery systems resulted in better projects based on certain output metrics as determined by the Expert Panel.

Project Delivery System	N	Mean	Std Deviation	t-value p
Budget Control: DBB	101	0.9382	0.0766	1.686
CM/GC	112	0.9541	0.0718	0.093
Schedule Control: DBB	97	0.9400	0.1293	0.451
CM/GC	102	0.9310	0.1321	0.653

Table 11: Group Statistics for the Oregon database[47]

[46] A Cardinal Change, in construction contract law, is a change that exceeds the magnitude or limits allowed by the contract or implied warranties, thereby allowing the contractor to seek compensation on the basis of "quantum meruit" or the "value of the work" provided [71]

[47] The reader will note that the numbers of cases are not the same for each Metric; this is due to the fact that some information is missing in some of the cases and zeros have been omitted from this statistical analysis. In the case of the DEA analysis that follows, zeros are included in the output measure.

Table 11 above presents the Group Statistics for the two populations: DBB and CM/GC projects. What this analysis tells us is that while there are differences in the population, they are slight and not statistically significant. The important thing to note here is how little variance there is in the principal output metrics.

4.1.2 Validation and Comparisons with Other Studies

In this section the statistical analysis of the principal output metrics from this study are compared with the other studies identified in Chapter 2, principally: [75, 99, 183] and the CII Benchmarking Study update. In order to do this, we convert the data into the format used by the other studies.[48] A summary of the studies is given below in Table 15.

[48] Note that for the purposes of the DEA analysis this study used cost and schedule control, defined as the planned divided by the actual performance. In the CII studies, the statistic used was [(actual-planned)/planned]*100, which gives a % difference (increase or decrease) from the planned performance.

Study	Number of Projects	CM/GC				DBB			
	Total: (CM/GC – DBB)	Cost		Schedule		Cost		Schedule	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Oregon Database	215 (111-104)	5.35	8.14	10.46	22.18	7.77	14.6	9.40	22.37
Washington Data [99]	16 (16 - 0)	7.19	7.09	N/A	N/A	N/A	N/A	N/A	N/A
		Median[49]		Median		Median		Median	
Oregon Database	215 (111-104)	4.00		0.00		4.90		0.00	
CII [183]	176 (72 – 104)[50]	3.37		0.00		4.83		4.44	
		All Projects							
		Cost		Schedule		Cost		Schedule	
		Mean	SD	Mean	SD	Median		Median	
Oregon Database	215 (combined)	5.88	7.49	9.98	22.24	4.9		0.00	
CII Benchmarking Study [51]	26 (unknown)	7.9	10.4	4.9	11.0	7.2		2.9	

Table 12: Summary comparison of different study results on the common project performance metrics cost growth and schedule growth, given in percentages.

Table 15 is a summary of the Oregon database results transformed from the metrics used in this study to the metrics used in the CII and state of Washington studies on PDS performance. The comparisons reveal that the Oregon database results are substantially similar to the earlier studies. As we noted in Chapter 1, the only metric comparison whose difference is greater than 5% is the comparison between the schedule performance in the CII Benchmarking Study [51] (which included only 26 projects) and the Oregon database on schedule performance. However, the standard deviations of both populations is significantly larger than the difference in the means ($\sigma \approx 11\%$ in the CII data and 22% in the Oregon database). It is interesting to note the difference in the mean and median schedule performance metrics in the comparison of the CII Benchmarking data and the

[49] In [183] reported the Median and not the Mean for both cost and schedule increase; data from the Oregon Database is presented likewise for comparison.
[50] There were 315 projects total in the CII study ([183] at p. 68), but only 176 of those were DBB or CM/GC, 44% (139) of their projects were Design-Build. The CII Study does not break down the data by project type, e.g.: buildings as opposed to bridges or chemical/industrial plants.

Oregon database. While the means are slightly more than 5% apart (4.9% compared to 9.98%), the medians are a lot closer; just under 3% apart (2.9% compared to 0%). It is also interesting to note that the Oregon database has a higher mean but lower median than the CII data. This is due, of course, to the large number of "on-time" projects (a lot of which are schools) in the Oregon database (and there are no schools in the CII data.).

Sanvido and Konchar state in both [183] and [75] that they used the median measure because it would reduce the impact of outliers in the data, and we see here that their concerns are at least partly borne out. Of course, the problem with using the median, as discussed earlier, is the fact that it does not reveal much about the population, such as the variance of the data, which is very important to project owners. While it is helpful to have a median cost growth of zero, if the variance is very great, the actual probability of realizing zero cost growth may be quite small and the risk of going greatly over budget or under budget may be quite high.[51]

The comparisons with the other studies in the literature validate the Oregon database results and data collected.

4.1.3 Study Results on Schedule Performance

In this and the following section the project output statistics are given in graphical box-plots in order to visually compare the different studies. This research project is

[51] For example, assume that there are 101 projects in the database, 50 achieve cost growth of minus 5%, one has cost growth of 0% and 50 have a cost growth of 100%. The median of this data is 0% cost growth; however, the likelihood that the owner will achieve 0% growth is less than 1%, while his likelihood of having his costs less by 5% are slightly less than 50%, and the likelihood of his costs increasing 100% are likewise approximately 50%. In fact, the owner's expected increase is not 0%, but rather a 47% increase in cost.

presented first, followed by [183], and [51], which does not present the data by PDS, but nevertheless is useful information for comparison.

PDS Type	N	Mean	Std. Deviation	Median
DBB	96	9.4%	22.37%	0.00
CM/GC	102	10.46%	22.18%	0.00

Table 13: Oregon database mean, SD and median for Schedule Performance over-run% the metric used in the CII studies for comparison purposes

Note that Table 13 indicates that there is schedule performance data missing for some projects in the Oregon database as was discussed earlier, in Chapter 3.

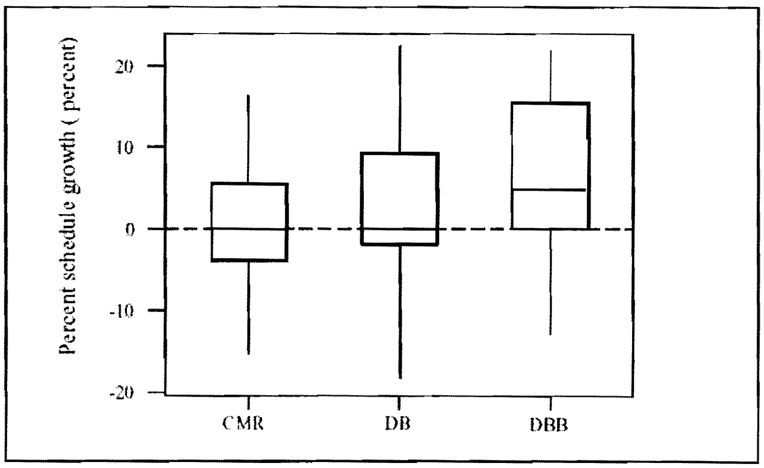
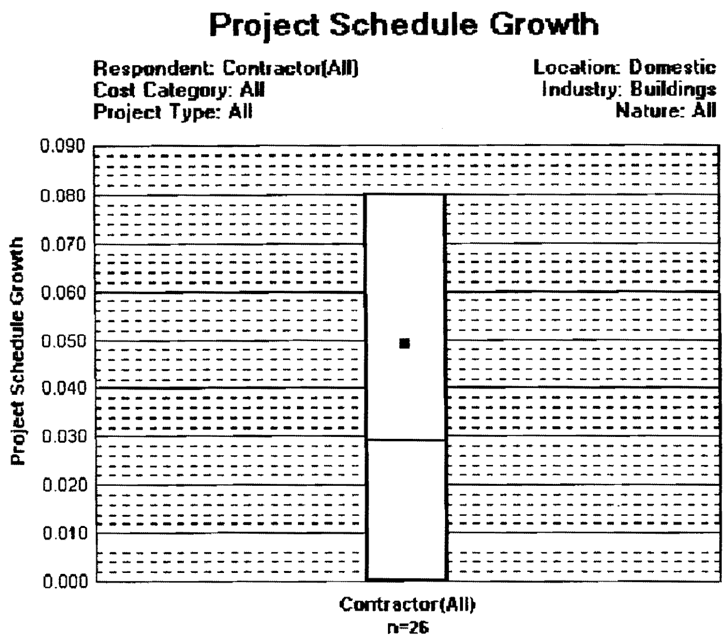


Figure 18: % Schedule Growth from CII studies [183] and [75] for comparison with the Oregon database



	Contractor(All)
Best	-0.136
100%	0.324
75%	**0.080**
50%	**0.029**
25%	**0.000**
0%	-0.136
Mean	**0.049**
SD	0.110
n	26

Figure 19: Project Schedule Growth from CII Benchmarking Study [51]. Note here that Schedule Growth is given as a decimal, not a %, and represents all projects in the study, regardless of l PDS

The scales of the graphical representations are clearly not similar, and therefore it is difficult to make direct comparisons; however, the output graphics and descriptive statistics do provide valuable information about schedule growth. The Oregon database results collected for this research indicate a mean schedule growth for CM/GC of 10.46% and 9.4% for DBB. These figures cannot be compared directly with any of the other studies, since none of the other studies reported mean and standard deviation data by PDS. However, when CM/GC and DBB jobs are combined, the overall project schedule increase of 9.94% with a standard deviation of 22.24% compares with the CII Benchmarking study [51] for all domestic building projects, which indicates a 4.9% mean schedule growth with a standard deviation of 11%, on a population that was a small fraction of the sample size data collected for this research. Given the data from the CII study [51], it would not be possible to reject the hypothesis that the CII Benchmarking Report data was drawn from the same population as this research.

The median schedule growth reported by the CII in [183] of 0.0% for CM/GC and 4.44% for DBB compares with 0.0% for CM/GC and 0.00% for DBB from the Oregon database. One possible reason for the difference may be the populations themselves. In the Oregon database, the DBB jobs include a large portion of school buildings that, for the most part, opened on time. Approximately 55% of the DBB jobs in the Oregon database reported 0.0% schedule increase. In the CM/GC projects 47% of the jobs reported 0.0% schedule growth. With such a large proportion of "on-time" jobs, it is unlikely that the median would be anything other than 0.0%. But, as discussed above, the project owner is not necessarily as concerned with the median of the population data as she may be with the variance in the population and the expected value and probability of going over budget and beyond the project's contractual schedule requirements, because that represents the project risk that has to be taken into consideration when the contract for construction is signed. It should be noted also that the Oregon database includes some extreme outliers in the schedule performance metric in both the CM/GC and DBB populations; that does not appear to be the case in the CII studies.

When the Oregon database results for schedule growth are plotted in a Box & Whisker plot using the mean, standard deviation and 95%, instead of the median, 25%, 75%, and maximum range of the data, the two populations are hardly distinguishable from one another. Furthermore, the graphical effect of the outliers is greatly ameliorated.

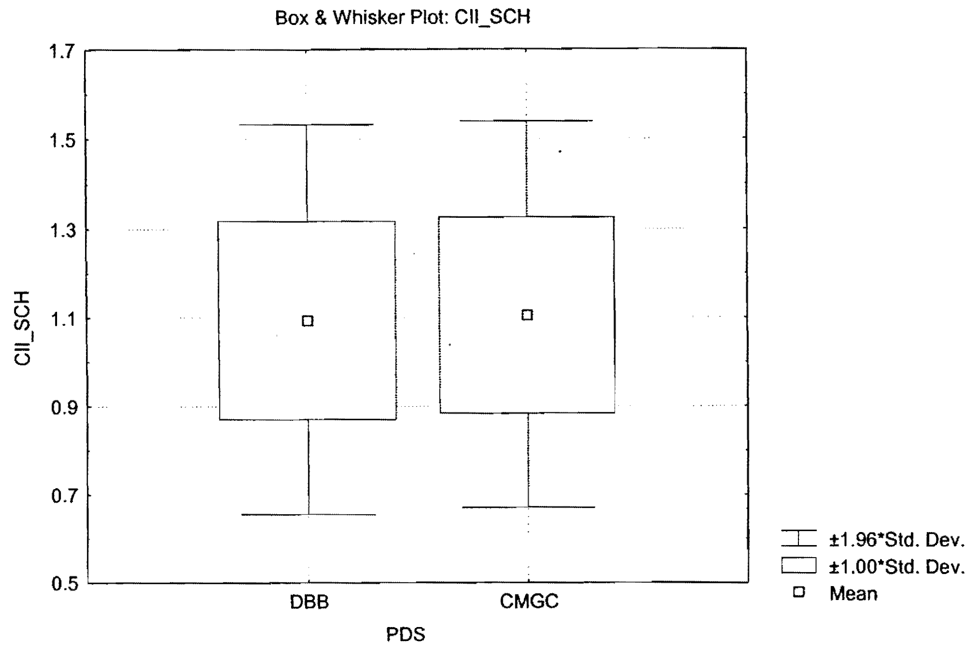


Figure 20: Box & Whisker Plot of the Oregon database using the CII study metric % Schedule Growth, graphing the Mean, Standard Deviation, and 95% data ranges

4.1.4 Study Results on Cost Performance

In order to compare data from this research study with that of the CII, the data was converted to percent increase ([Final Cost-Original Cost]/Original Cost). The group statistics results from this study are given in Table 14 below.

PDS Type	N	Mean	Std. Deviation	Median
DBB	100	7.77%	14.6%	4.00
CM/GC	110	5.35%	8.13%	5.00

Table 14: Oregon database mean, standard deviation and median for Cost Performance over-run%, the metric used in the CII studies for comparison purposes

When the same metrics the CII studies [75, 76, 183] are used to compare budget performance, the CM/GC projects show a 5.35% increase on average, whereas the DBB projects realize a 7.77% increase, but the difference is not significant.

A comparison of the box plot Figure 21from this research actually shows that while the mean of the CM/GC projects is slightly lower, the DBB project data is more compact than the CM/GC data; however, DBB appears to include more extreme outlier cases than CM/GC, which represents greater expected risk as noted earlier.

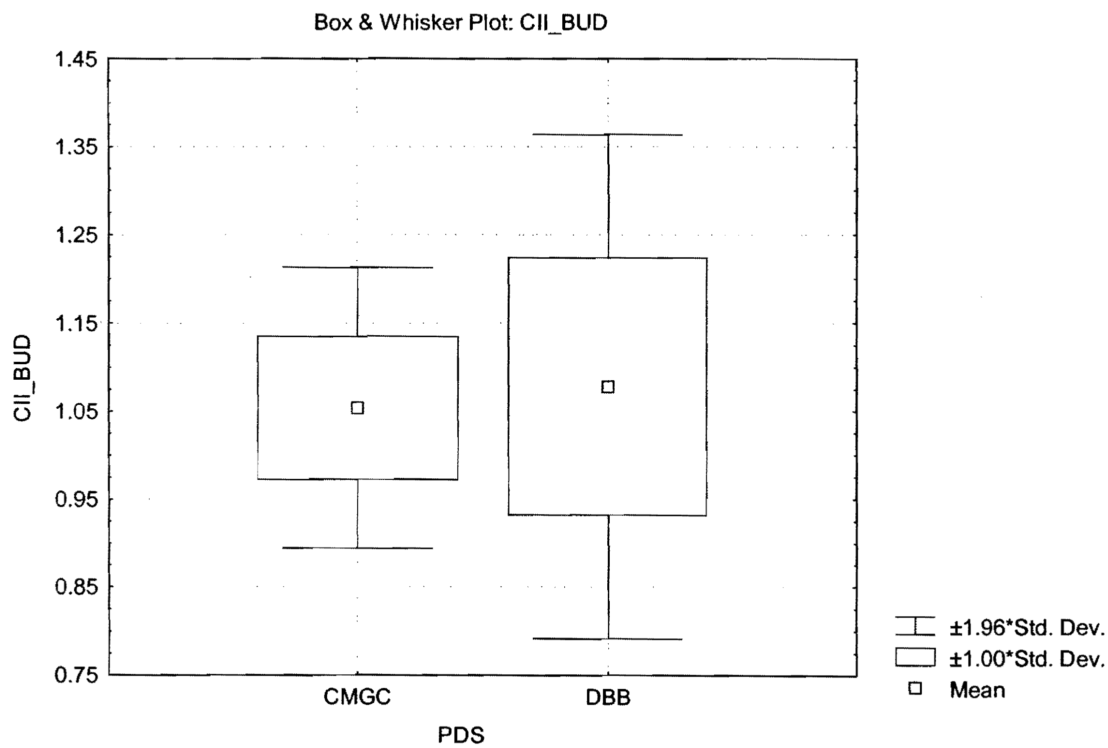


Figure 21: Box and whisker plots of the Oregon database results using the CII cost performance metric, Cost Growth as actual/expected, for comparison with the CII results

Figure 21, compares to the % Cost Growth Box Plot found in [75, 183] from the CII, here Figure 22:

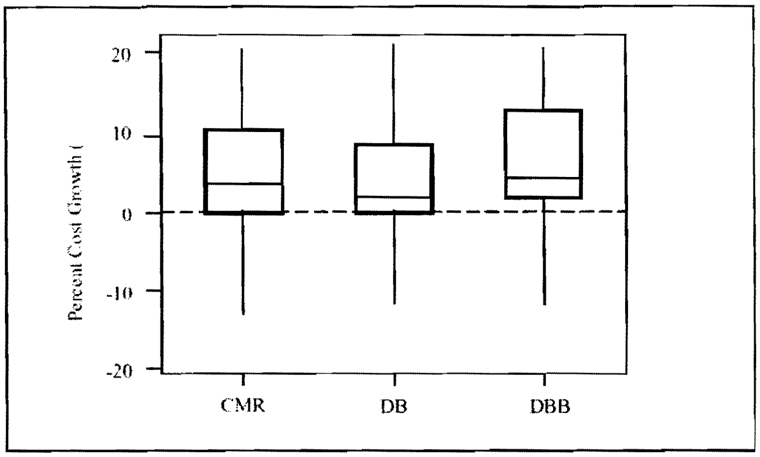
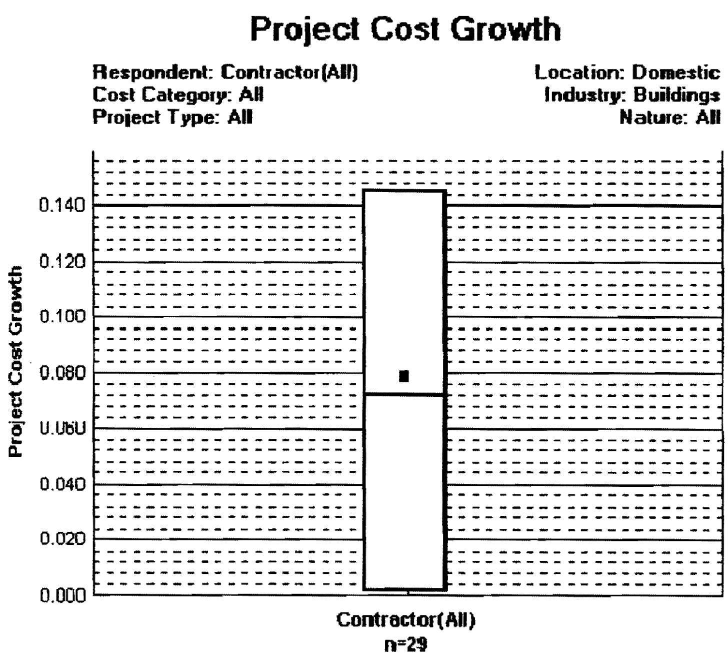


Figure 22: % Cost Growth from CII Studies

Also, the CII Benchmarking Study BMM2001-1 [51] analysis for all domestic building projects without regard to PDS is given below in Figure 23:



	Contractor(All)
Best	-0.120
100%	0.330
75%	**0.145**
50%	**0.072**
25%	**0.002**
0%	-0.120
Mean	**0.079**
SD	0.104
n	29

Figure 23: Benchmarking Study Figure #1310, Cost Growth for All Domestic Buildings

The CII Benchmarking study [51] for all domestic buildings, regardless of the PDS, has a mean schedule growth of 7.9% with a standard deviation of 10.4% and a median of 7.2%; however, this part of the CII study included only 29 projects. The results from Goldblatt and Septelka [99] for CM/GC projects is found in Appendix E; again, as with the CII Benchmarking study, [99] had a very small sample population. Nevertheless, a similar mean cost growth of 7.19% and Standard Deviation of 7.10% was recorded. This data is presented graphically in Figure 24.

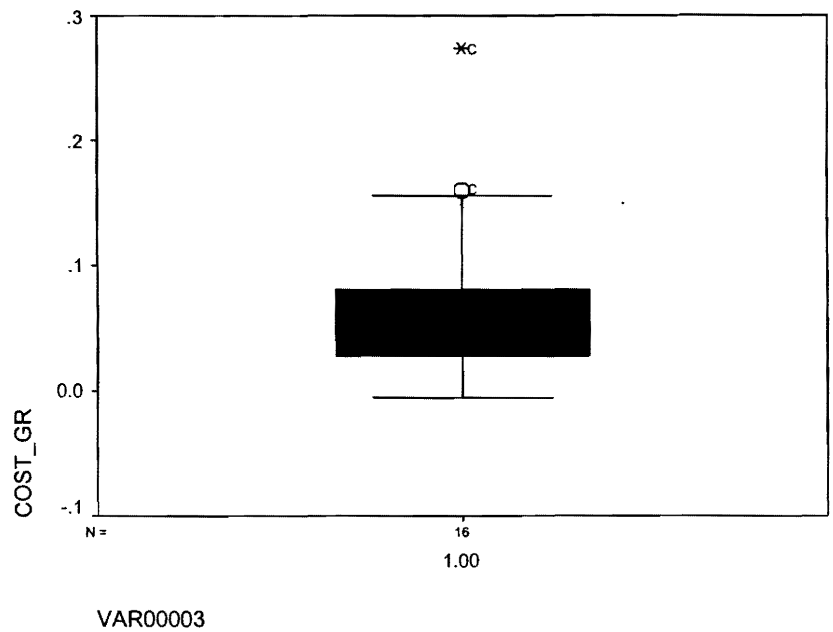


Figure 24: Box Plot of Cost Growth from the Washington data in [99]

4.1.5 Summary of the Comparisons

In order to make direct comparisons between the Oregon Research Data, the CII studies [51, 75, 183], and Washington state report [99], the data from this study had to be transformed into consistent measures. When this was accomplished, a comparison between the different studies could be made. A summary of those comparisons is presented in Table 15.

The most striking observation from these comparisons is how similar the results of the different studies actually are. The only significant difference is the median schedule growth reported in [183] of 4.44% compared with the Oregon database, which yielded a median of 0.00%. However, as pointed out above, the Oregon database was exclusively public buildings, whereas [183] was heavily weighted toward industrial projects. In the CII Benchmarking Study [51], where the comparable data was found to be construction contractor reported and domestic building data, the study used only 31 projects (although not all 31 projects were used in each analysis,) where this research collected data on nearly seven times that amount. Nevertheless, the differences in the project data analyses are not significantly different.

The most interesting observation is that in spite of the fact that these data analyses are not significantly different, the CII [183] found that the CM/GC PDS delivers projects faster and controls growth better than the DBB PDS claim that is then repeated in [76].

4.1.6 Results of the Analysis – Research Question 1

The analysis shows that we reject the hypothesis that CM/GC projects out-perform DBB projects on schedule and cost control metrics. However, a valid interpretation of this analysis is that the CM/GC is not better than DBB, but it likewise is no worse, and that the public pays no additional price in terms of cost and schedule growth for starting a project earlier by using CM/GC. But the analysis does call into question the public policy that requires CM/GC projects to provide the public with "substantial cost savings."

4.2 Research Question 2: Efficiency Analysis

The scatter plot presented in Figure 15 is a useful representation of project outcomes when inputs are not considered. Our research was intended to consider both inputs and outputs. However, the important thing to note from Figure 15, and from out statistical analysis presented above, is that the project outputs are not dramatically dissimilar. In fact, while there is quite a range of outputs, particularly in the schedule performance metric, the vast majority of the projects had performance outputs that were substantially similar, with few truly outstanding and few truly horrible projects and no standout or single dominate project. Even those projects that did poorly on one of the two metrics appear to have made up for it in the other

In this section we seek to determine if, when both inputs and outputs are considered, CM/GC projects are more efficient than DBB projects. To do this we test the hypotheses:

> H_{A2}: CM/GC projects are more efficient than DBB projects, where efficiency is defined by a DEA model that considers both inputs and outputs from the construction process model.
>
> H_{02}: There is no significant difference between CM/GC and DBB projects with respect to efficiency scores where efficiency is determined by a DEA model that considers both inputs and outputs from the construction process model.

4.2.1 Initial DEA Model Analysis (CRS and VRS Models)

The normal method for evaluating DMUs in DEA is by application of either a Constant Returns to Scale (CRS) model or a Variable Returns to Scale (VRS) model.

These models have been used throughout the literature and applied in a number of different industries and economic sectors. However, neither the traditional CRS or VRS models is well suited to the evaluation of the data set in this research. This is because of the peculiar fact that the inputs vary so substantially but the outputs do not, which is the distinctly non-linear relationship between inputs and outputs in the mode. Traditionally, when a researcher wanted to evaluate a data set of DMUs with extreme differences in input and output metric values such as comparing grocery stores and including mini-marts, traditional mainstream stores, and warehouse stores in the same data set, the researcher would apply a VRS model; however, this would not work in our case because it is a distinctly different type of non-linear relationship.[52]

To check this assumption, we ran the VRS model which resulted in only 130 of 215 total projects with greater than 50% efficiency scores, and 48 of 215 with better than 90% efficiency score is depicted in Figure 25 below. These results do not correspond to either the results of the statistical analysis (Table 11 above) or the output scatter plot depicted in Figure 15, nor do they match the perception of the Expert Panel Members who uniformly maintained that, except in rare cases, projects should fall within a narrow range of results.

[52] In the grocery store example the mini-mart has small inputs and small outputs, the warehouse store has large inputs and large outputs. However in this research we have projects with small inputs and medium outputs and those with large inputs and medium outputs.

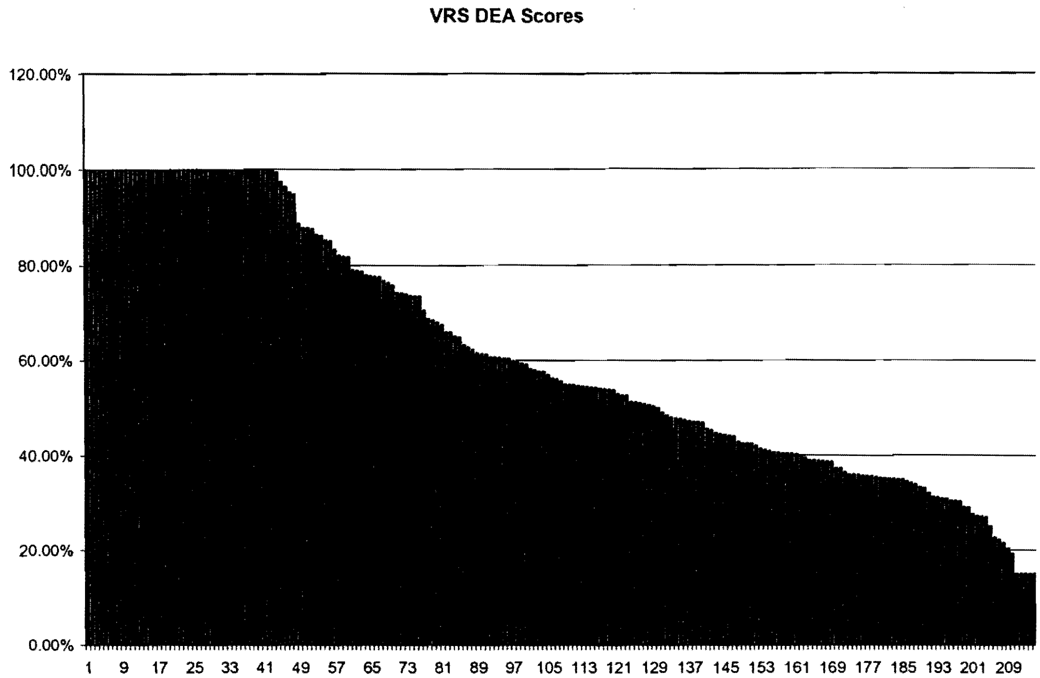


Figure 25: VRS DEA Scores - Base model with efficiency score on the Y axis and projects plotted on the X axis.[53]

It is probably intuitive, but the results of a CRS model are even worse than the VRS model. The CRS model resulted in only 16 of 215 projects with efficiency scores above 90% and only 87 of 215 with scores better than 50%. It should be obvious from these results that the application of either a CRS or VRS model without significant modification does not shed any light on the analysis of this construction project data.

4.2.2 Modifying the DEA Model for the Non-linear Construction Project Information Data

It is apparent why the VRS and CRS models result in the distribution of scores as they do; it is because the outputs lay within a rather narrow range and the inputs vary from

[53] Note that in order to produce this histogram the output oriented DEA scores in the VRS model had to be inverted.

0.25 to 1.0 (or 25% to 100% complete plans and specifications). Nearly all of the projects with plans and specifications of 100% complete will have efficiency scores below 50% - which is exactly what happens in this model. The problem comes in the evaluation of those input metrics. Recall that above we stated that there is no fixed standard for evaluating percentage complete, and the method we used was simply to ask the various parties to assign a number based on their past experience. This results in extreme non-linear relationships between the principal inputs and outputs. While there is basic agreement that "conceptual design," is less complete in terms of "% complete plans and specifications" metric than "schematic design" or "preliminary design" the precise estimates of these values varies. In other words, what one project manager means by 25% complete may be considered 35 or 40% complete by another.

The generic economic production model used in the Data Envelopment Analysis (DEA) methodology assumes a linear relationship between inputs and outputs even though we are unaware of precisely how those inputs are converted to outputs. The VRS model allows for economic comparisons among a relatively narrow range; however, the basic assumption that underlies the formulation remains the linear relationship between inputs and outputs, and the VRS model does not handle problems where there are extreme non-linear relationships between inputs and outputs.[54]

There are a number of commercial institutions where the economic transactions can be characterized by non-linear relationships between inputs and outputs – in particular,

[54] Some have suggested transforming the data using logarithms or other methods, but these transformation methods would require a strong theoretical foundation and none is known for this situation.

those where there are limiting boundaries for either measure or endogenous effects that cannot be fully captured. This is particularly true with professional services where input resources like "information" and output measures "time" and "cost" have definite fixed boundaries. One example is weather prediction. Given very little information such as the desired location and having some idea of the historical climate, it is easy to predict the weather at the location within a given range. For example, we can say that the temperature in Portland, Oregon tomorrow will range between 5° Fahrenheit and 105° F. We can say this no matter what the time of the year that the most extreme temperatures ever recorded in Portland fall within these boundaries. With a little more information, such as the day of the year requested, we can narrow that range significantly. But no matter how much money we invest, we know that we cannot exactly predict the weather six months from now. Therefore, there is a distinctly non-linear relationship between the amount of information paid for and obtained as an input, and the accuracy of the prediction of the weather as an output.

The same relationship can be said to be true in the construction sector of the economy. Since we know that the cost of construction is finite and exists within some approximate range, say between $10 and $500 per square foot, a very broad estimate on any building project can be made with little or no information. The amount of information collected by the owner and transmitted to the contractor narrows the range of costs considerably, but more information simply cannot eliminate the variability or range entirely, in part because the building environment exists in nature, the state of which cannot be reliably predicted well out into the future. The question many owners want answered is, "how much information should I pay for in order to reduce the uncertainty in the pricing and how much information is simply a waste of resources, given a limited budget?"

It is also important to note that the analysis set forth in Table 11 and described in Figure 15 supports Kagel and Levin's point [118], and our conclusion that the amount of actual "Information" provided is not fully captured by the metric "% complete plans and specifications" in spite of the fact that the Expert Panel recommended it. This is because the metric fails to take into account the economic reality of the industry and the amount of training and experience of the estimators and managers of the construction companies involved, which is substantial[55]. This is perhaps better visualized in the Process Model suggested by Figure 26.

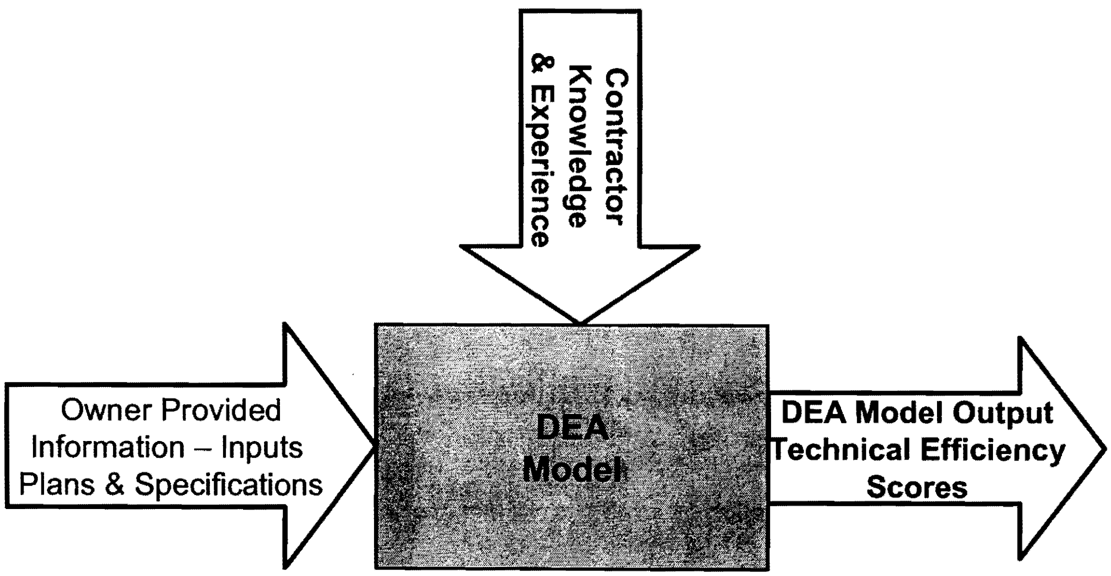


Figure 26: DEA Model revised to reflect the Construction Industry setting where the amount of information provided by the owner is greatly complimented by the contractor's own knowledge and experience

[55] One reason for limiting the projects to a certain size, larger than $5 million, was because we knew that only construction firms with substantial resources and experience can qualify for Miller Act, performance and payment bonds, for that size of work.

We know both from our own study and from industry standards that the cost per square foot of public buildings of virtually all types resides within a relatively small range. For example, *RS Means Building Construction Cost Data* estimating guide provides a section that provides per square foot cost estimates for approximately sixty different type buildings from apartments to warehouses. This data includes estimates at the 25 percentile, median and 75 percentile ranges. Furthermore, while these data are determined by national averages, the guide also provides regional indexes to convert the average costs to a cost for a specific area. Portland, Oregon, for example, has a weighted average of about 1.06 times the national cost average for buildings, according to *Means* [212].

Armed with a commonly available estimating guide and experience in the local construction market, it is possible, easy in fact, for a construction estimator to narrow the range of possible costs far tighter than an input of 25% to 100% would imply. So, for the purposes of a DEA model, is it possible to account for this base of knowledge that is an additional "resource" (or enhances the Information provided resource) that results in "production" from the model? And the answer to that question is, probably, though probably not to a level of certainty that makes the evaluation meaningful. Also, while we did collect data on the different construction companies, none of the data we collected as a proxy for experience (including number of years in business, bonding capacity, project team experience and so on) could be reliably tied to a single input metric for "knowledge" that would differ significantly from company to company. This, again, would make the input meaningless (if, for example, all the companies had the same input value).

In situations where the inputs and outputs are not directly linearly related and the exact relationship is unknown or not captured by known inputs, a possible approach would be to apply a "categorical" variable model. If applied here that would mean that projects for which only "conceptual design" has been completed would not compete directly with projects that have complete or "final design" complete jobs. They would only compete with other projects that have projects whose plans and specifications are similarly in the conceptual phase. However, that would render meaningless the point of this research, which is in part to compare the PDS by outcome against one another and determine if one type is significantly superior to the other.

Another possible approach would be to use ordinal categorical values, such as A > B > C, where all members of category A are compared against both the members of category A, and also category B and C. Members of category B would only be compared against members of B and C, and members of C are compared only against themselves.

The decision was made to apply a modified ordinal categorical model using successive data sets that included: 1) all project data; 2) only projects with higher than 40% complete plans and specifications; 3) only projects with higher than 75% complete plans and specifications; and finally, 4) only projects with higher than 95% plans and specifications (in other words, only those that had the design complete).

This process can be visualized as in Figure 27 below:

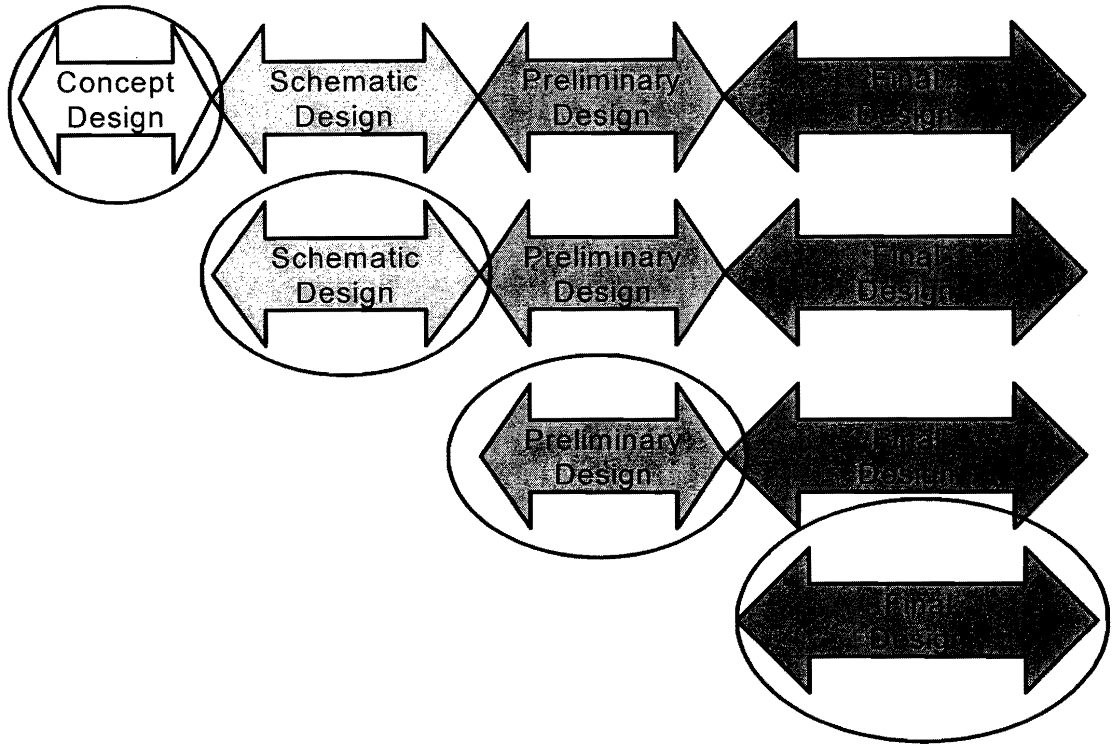


Figure 27: Conceptual structure of the modified ordinal categorical DEA model, where DEA scores for concept design are derived in a comparison against all categories, schematic design projects are compared against only schematic, preliminary and final design category members, preliminary design members are compared against preliminary and final design category members, and final design category members derive their DEA scores in a comparison solely within the final design category members.

In the first run of the model, the "conceptual design" projects actually compete against all other projects for their technical efficiency scores and once these scores have been determined the "conceptual design" projects are dropped from further analysis. In the next round, "schematic design" level projects compete with all of the remaining projects in the Oregon database for their technical efficiency scores. Once they have been determined, these projects are removed from the model and the process is repeated for the "preliminary design" level projects. Finally, the only projects that are left are the "final design" level projects, which compete only against themselves for their technical efficiency scores.

The controlling direction of the analysis was guided by state statute. In Oregon, as nearly every other state, on public building projects, the state gives priority to open public bidding and discourages closed negotiated procurements except when it can be shown to be a substantial benefit to the public. The relevant portions of the particular Oregon statute, ORS 270.015 are as follows:

> **279.015 Competitive bidding**; exceptions; exemptions. (1) Subject to the policies and provisions of ORS 279.005 and 279.007, all public contracts shall be based upon competitive bids or proposals except:
>
> (2) Subject to subsection (6)(b) of this section, the Director of the Oregon Department of Administrative Services or a local contract review board may exempt certain public contracts or classes of public contracts from the competitive bidding requirements of subsection (1) of this section upon approval of the following findings submitted by the public contracting agency seeking the exemption:
>
> (b) **The awarding of public contracts pursuant to the exemption will result in substantial cost savings to the public contracting agency.** In making such finding, the director or board may consider the type, cost, amount of the contract, number of persons available to bid and such other factors as may be deemed appropriate.
>
> (3)(a) Before final adoption of the findings required by subsection (2) of this section exempting a contract for a public improvement from the requirement of competitive bidding, a public agency shall hold a public hearing.

It is clear from these sections of the statute that the Oregon Legislature intended to make the option of exempting from bidding and negotiating public building contracts a difficult and well reasoned alternative to open competitive public bidding, but certainly an option. Since the state has established the baseline PDS to be DBB, then the negotiated procurements, the CM/GC projects, must be considered the "challenger." Therefore, the challenger, which is disfavored in the statute, has the burden to show it is superior against the baseline, whereas the baseline has no such burden. It is reasonable to argue that this being the case, there is no need to evaluate the different levels of information in terms of the Percent Complete metric, rather, simply run all CM/GC jobs categorically against all competitors, and then run only the DBB projects to establish their efficiency scores. While this obviously can be done, we wanted a finer break-out from the analysis.

4.2.3 Results from the Modified DEA Model

We did not recode the existing computer software, but instead the Modified DEA Model was run using EMS® Software from project data, stored in an Excel® spreadsheet. Four passes were made on the data each using a Constant Returns to Scale (CRS) input-oriented model as described above. (We note that the proper theoretical model for this application is the output oriented DEA model, however we used the input oriented model for ease in reporting the efficiency scores. Since we used the CRS model (in absence of weight restrictions), we can make use of the fact that the DEA scores in the input and output oriented CRS formulations are merely reciprocals of each other [64] and provide the same results. By using the input oriented model, we simply save one step of calculations.)

The results of this process are depicted in Figure 28 below:

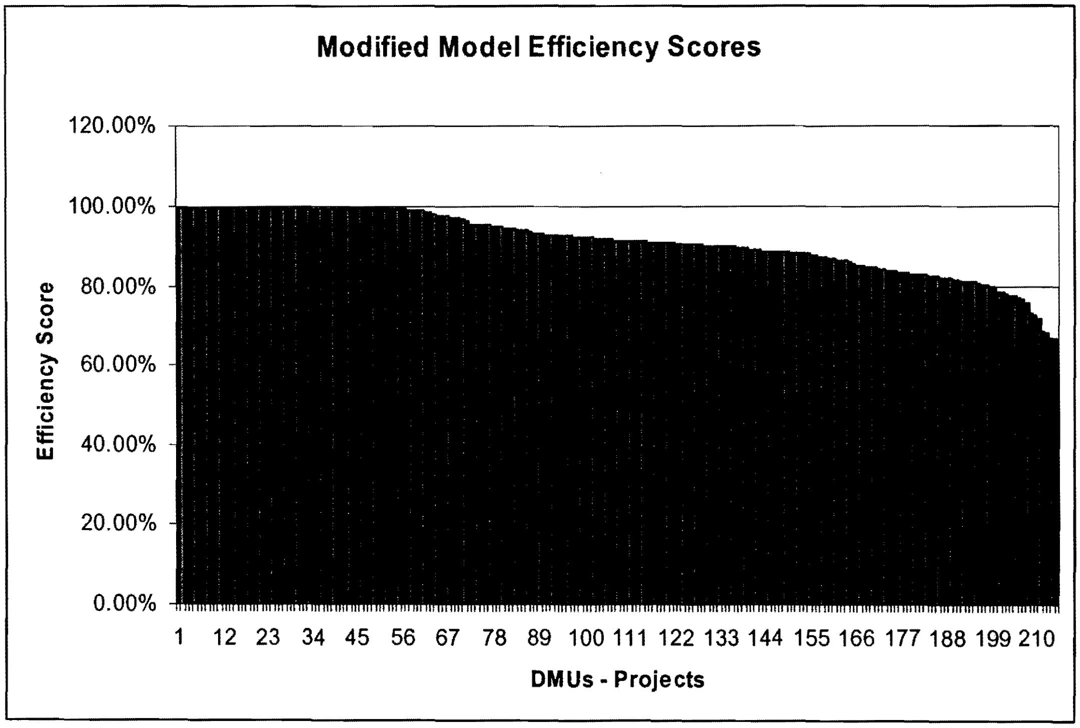


Figure 28: Modified Model Efficiency Scores

The DEA efficiency scores from the Modified model range from approximately 67% to 100% and have an arithmetic mean of 91.52%[56] and a standard deviation of 7.76%. Also shown is a single frequency histogram of the DEA efficiency scores from the Modified Model, presented in Figure 29.

[56] DEA scores are known to be non-normally distributed bounded by: 0.0 and 1.0; however, both the arithmetic mean and the standard deviation do provide us with valuable information about the distribution of the DEA data.

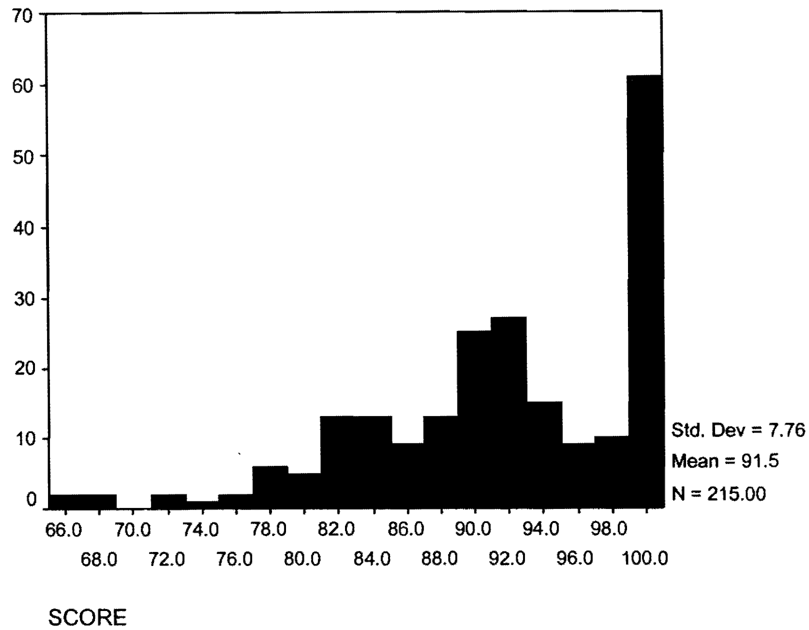


Figure 29: Histogram of all DEA efficiency Scores from the Modified Model reflects a common DEA distribution, a relatively continuous distribution with a local maximum, above at about 92%, and a large number of 100% efficient DMUs at the far right.

The results obtained by the Modified Model are more consistent with the Expert Panel's intuitive understanding of construction project performance than the results obtained in the earlier DEA models depicted in Figure 25. Fifty-seven of the 215 projects in the final data set were determined to be 100% efficient, and 140 projects scored 90% or higher.

4.2.4 Model Verification

To verify that the DEA model could be used to analyze construction projects in the manner prescribed by this research, we reviewed projects that were both rated highly efficient and those rated inefficient to determine if these ratings accurately reflect the project performance. (We did not review each and every one of the projects.) Verification was accomplished in several steps, and these included using super-efficiency methods and analysis to the comparators to explore project dominance in the peer groups. (See [226] for a discussion on Super Efficiency on page 217.) The analysis of comparators is accomplished by reviewing, what the EMS software terms as "benchmarks," the efficient DMUs, which all inefficient DMUs are compared to and all virtual DMUs are constructed from. The super efficiency method was helpful in "debugging" the initial model runs and finding data that was suspect. (Most importantly was dealing with missing data on the input side of the model for specific projects.) In the final analysis, the super efficiency of the most-used benchmark project was 158%, and the highest super-efficiency score was 309% on a project that was used by 49 others as a benchmark. The latter project earned a high-quality output score while starting with project information at 40%.

Of the DBB project data, the top five efficient projects were used as benchmarks in the following order: 95, 72, 26, 18, and 9 times by the inefficient projects. The top two jobs were used as benchmarks significantly more often than any others. These jobs were a new construction higher education building and a remodel of another higher education facility. The former project completed on time and was under the original bid amount, while the remodel project experienced both cost and schedule growth but achieved a low cost per square foot in spite of having a low input level and quality of information.

The CM/GC projects had a more efficient project than DBB, and the distribution of comparators or benchmarks was found to be more dispersed. The top five efficient projects were used as benchmarks for the following number of projects: 176, 154, 137, 85, 81 and 76. The first project was a new high school project with both the architect and contractor estimating the plans and specifications to be no more than 15% complete at the time the GMP was agreed upon. While the project incurred significant cost growth, the project was completed within the contract period, opening in time for the school year to begin. The second project was a new corrections facility that started with 75% complete plans and specifications and finished on time, on budget and earned the contractor his expected fee.

The reason the CM/GC jobs are used as benchmarks by 176 and 154 projects, as opposed to 95 and 72 for DBB jobs, is due to the way the modified model was constructed. Most DBB projects were started after final design was complete and therefore their benchmarks were established principally using only other DBB projects, whereas most CM/GC projects were compared against all 215 projects in the data set.

The lowest rated projects among both the CM/GC and DBB jobs were those that either had missing data, thus reducing the number of pathways to the efficiency frontier, or were at the high end of the amount of information (input) in their peer group, an aspect of non-linearity that we were not completely able to eliminate. (However, this drawback would not affect the outcome of the analysis as demonstrated in the following section.)

Based on the above analysis, we conclude that the modified model adequately reflects the building construction environment, and the model scores can be used to compare the performance of the PDS's.

4.2.5 Evaluating the Project Delivery Systems

The next step in our analysis was to evaluate the two project delivery systems, DBB and CM/GC based on their DEA technical efficiency scores. This was done by applying normal statistical methods, reserving, of course, the same caveats about statistical analysis of DEA score distributions that was previously discussed. Both the group statistics and the tests for independence are presented in Table 15 and Table 16 respectively.

PDS	N	Mean	Std. Dev
CMGC	111	92.50%	8.59%
DBB	104	90.48%	6.64%

Table 15: Group Statistics of DEA Scores from the Modified Model

Note from the analysis in Table 15 the difference between the means of the two populations is just over 2%, with CM/GC projects having a slightly higher mean technical efficiency score. However, Table 16 below indicates that the difference in the two populations is not quite statistically significant at the 95% level (although it is quite close with p = 0.056).

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t.	df	Sig (2-tail)	Mean Diff	Std Error Diff	95% Confidence Interval of the Difference Upper	Lower
Score: Equal Var. Assm'd	9.89	0.002	1.92	213	0.056	2.02%	1.05%	-.052%	4.10%
Score: Equal Var. not Assm'd			1.93	205.7	0.054	2.02%	1.04%	-.036%	4.08%

Table 16: Test for Independent Populations for PDS based on DEA Scores from the Modified Model

This statistical analysis of the DEA scores gives similar results as that produced on the base output data analysis presented in Table 11. That is, in spite of the fact the CM/GC negotiated procurements have a slightly higher average, the difference between CM/GC and DBB is not statistically significant in terms of DEA scores from the modified model.

One interesting note is that the CM/GC projects have a greater range in efficiency scores than the DBB jobs. Levene's test for equality of variances shown in Table 16 finds that the variances, and therefore the standard deviations of CM/GC and DBB projects, are significantly different. These results indicate that while the means may not be statistically different, the CM/GC projects may pose the greater risk in terms of cost and schedule growth. It also indicates the owner has a greater range of possible project savings.

4.2.6 Nonparametric Methods of Comparison

Since DEA is a non-parametric method and the DEA scores are distinctly not normally distributed, another way of evaluating any difference in the two populations is to actually look at the distributions and apply non-parametric techniques. Observing these two populations we note that the CM/GC projects have a higher proportion of 100% efficient projects than do the DBB jobs. In fact, 41 of 111 CM/GC projects were determined to be 100% efficient, whereas only 15 of the 104 DBB jobs were determined to be 100% efficient. However, this difference becomes less distinct when you compare all projects with 90% or better efficiency scores; in that case, 64 of the 104 DBB jobs scored better than 90% efficient, while 74 of the 111 CM/GC projects scored 90% or better. And, on the other end of the spectrum, six of the 111 CM/GC projects scored less than 75% efficient, whereas only one of the DBB jobs scored lower than 75%. This is probably due to the fact that information provided in the DBB projects is more consistent (since nearly all DBB jobs have 100% complete plans and specifications), whereas the CM/GC population of projects have a broad variation in the amount of information (ranging from 15% to 100% complete plans and specifications).

Section 2.14 discusses different types of nonparametric statistical methods for evaluating populations that, like DEA scores, are not normally distributed. One of those tests is the Mann-Whitney and Wilcoxon tests (which give the same results through two different methods).

PDS	N	Mean Rank	Sum of Ranks
DBB	104	95.86	9959.00
CM/GC	111	119.47	13261.00
Total	215		

Table 17: Mann-Whitney Nonparametric Rank Method Analysis

The test statistic Z of -2.82 and level of significance at 0.005 indicates that the DEA scores are not from the same population, and in this case the difference is significant. The DBB projects have a lower rank, but in this case, since the DEA technical efficiency scores range from 1.0 down, it means that the CM/GC projects in fact have a higher mean technical efficiency score, which is better. From this analysis, we can state that the CM/GC projects have a higher mean technical efficiency score, and that the difference is statistically significant.

In summary, the nonparametric analysis of the DEA technical efficiency scores results in a statistically significant difference between the two populations, whereas the normal parametric unvariate statistical analysis did not. Since the DEA technical efficiency scores are distinctly non-normal, the nonparametric analysis is more appropriate. From the nonparametric analysis, it can be said with some confidence that the CM/GC projects achieve higher DEA technical efficiency scores than DBB projects, and that the difference is statistically significant.

4.2.7 Results of the Analysis Research Question #2

Using non-parametric analysis to test the hypothesis:

> H_{A2}: Negotiated Procurement, Construction Manager/General Contractor (CM/GC) method of Project Delivery System (PDS) outperforms the traditional Design-Bid-Build (DBB) PDS method.

We cannot reject the hypothesis that the CM/GC projects outperform the traditional DBB PDS method projects in terms of overall project technical efficiency. However, one question that remains is, if the CM/GC projects do not outperform the DBB jobs in terms outputs but do in overall efficiency, can we determine why this occurs? (This question will be addressed below.)

4.2.8 No-input Model

Figure 15, the scatter plot of the Oregon database presented in Section 3.7 above, is similar to a two-dimensional DEA model that assumes no inputs, or where all of the inputs are equal to some number (in the specific case 1.0). A final run of the DEA model using 1.0 as the only input while using all of the outputs as in the previous model, in the same graduated method as before, was done. This model yielded fewer efficient projects, twenty-three (23) total; with eleven (11) DBB and twelve (12) CM/GC. Statistical and non-parametric tests were performed on these model results and indicated that while there were differences in the populations of projects by PDS, the differences were not statistically significant. This was probably to be expected given the earlier analysis of the output metrics discussed in Section 3.7.

The one important observation from this alternative model and analysis is that the significant advantage that CM/GC projects obtain in the DEA model accrues principally because of the inputs, in particular, the percent complete of plans and specifications.

4.2.9 Summary

In summary, the nonparametric statistical analysis of DEA technical efficiency scores showed that the CM/GC projects have, on average, higher technical efficiency scores, and the difference between the CM/GC and DBB populations is significant based on the non-parametric statistical analysis. We reject the null hypothesis that CM/GC projects do not result in projects that have a higher technical efficiency score, and we accept the hypothesis that CM/GC projects are more technically efficient than DBB projects. Furthermore, the analysis shows that a higher proportion of CM/GC projects are "technically efficient" (with 41 of 111 CM/GC projects compared with 15 of 104 DBB technically efficient jobs). Also, 55 of the 111 CM/GC projects had DEA efficiency scores of 95% or above, whereas 25 of the 104 DBB projects achieved DEA efficiency scores of 95% or above. Finally, the advantage that CM/GC projects enjoy accrues principally from the inputs, in particular the percent complete plans and specifications. This is the strongest evidence that fast-tracking of projects is the primary benefit of using the CM/GC PDS, since fast-tracking is one principal difference between the two PDS's (along with pre-construction services offered to the owner by the CM/GC).

There is no way to precisely determine if one method is more cost effective than the other, but theory and empirical study (such as: [135]) would suggest that on average, CM/GC projects are more costly than competitive bid projects due to the absence of other competitive bidders. This will be explored in more depth in Chapter 6 which is a case comparison of two similar projects.

The analysis of the DEA model input and output weightings gives some clues as to how the two populations maximized their DEA scores and made it to the production frontier. The difference between the two populations is slight but generally consistent with the comments made by the stakeholders in the stakeholder survey found in Chapter 5, specifically a greater focus on quality but a lower focus on schedule control. Looking at the data in another way, the slacks indicate the improvement required to reach the efficiency frontier given the weightings of the virtual DMU. There is an important point to note here: if, as in some cases with the Oregon database, a DMU has no data is reported for an output metric, the virtual DMU most likely does not utilize that output in its model and therefore no improvement is reported to be available – presumably because the comparator also did not use that metric. The analysis of the slacks indicates that there is no statistically significant difference between the populations of projects (CM/GC and DBB) with respect to improvement.

4.3 Research Question 3: PDS / Project type Interaction through Analysis of the DEA Scores and Weightings

This analysis was performed to determine if one of the PDS's outperformed the other on specific types of projects, that is, if there is some kind of interaction between project type and PDS based on DEA efficiency score. The intent here is to determine if some guidance can be offered to public agency project owners on the type of PDS they should consider using for specific types of projects. In other words, if, for example, PSU was going to build a library, can we determine if CM/GC or DBB is the more appropriate PDS to use?

We use the results from the Modified DEA Model obtained in the earlier analysis for the first part of this analysis, which looks at the mean and median DEA scores by project type to determine if there is any interaction between project type and PDS. The second analysis looks at the mean DMU weighting schemes to determine if there is a difference in the way each of the project types maximizes their particular DEA score. These weightings were taken from the EMS® software model using the "virtual weights" option, which reports the weighting schemes of the virtual DMUs associated with each inefficient DMU_i and of course, in the case of the efficient DMUs, EMS reports their weighting scheme directly. These weights are actually the $u_i\, x_{i,0}$ and $v_i y_{i,0}$ for the virtual and efficient DMUs, which results in a sum of 1.0 for all inputs and outputs in the model.

For this analysis we test the hypotheses:

> H_{A3}: CM/GC PDS results in projects that outperform DBB PDS on similar types of projects.

$H_{A3.1}$: When applied to corrections projects, CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.2}$: When applied to hospital projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.3}$: When applied to institutional projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.4}$: When applied to library projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.5}$: When applied to office building projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.6}$: When applied to parking structure projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.7}$: When applied to building remodel projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.8}$: When applied to school projects CM/GC PDS results in projects that outperform DBB PDS projects.

$H_{A3.9}$: When applied to sports facility projects CM/GC PDS results in projects that outperform DBB PDS projects.

H_{03}: CM/GC PDS does not result in projects that outperform DBB PDS on similar types of projects.

(Note the sub-hypotheses of the null hypothesis H_{03} are omitted for brevity.)

4.3.1 DEA Scores by Project Type and PDS

This analysis is performed to determine if one PDS or another works best in one particular situation or another, and to determine if one PDS or the other is significantly better for a particular type of project. In Table 18 below, the number of projects, mean DEA score, median DEA score and standard deviation of DEA score are given by project type and PDS.

Note that while these are non-normally distributed populations, the non-parametric methods generally will not work because those methods typically require an $N \geq 10$ [120], and while that is met for some of the comparison groups, it is not met for each of them.

Project Type	PDS	Number	Mean	Median	Standard Deviation
Corrections	**CMGC**	13	**0.935**	1.000	0.098
	DBB	3	0.926	0.949	0.087
	Total	16	0.934	0.995	0.093
Hospital	**CMGC**	1	**0.950**	0.950	.
	DBB	3	0.847	0.780	0.133
	Total	4	0.872	0.865	0.121
Institutional	**CMGC**	12	**0.946**	0.990	0.067
	DBB	13	0.905	0.886	0.069
	Total	25	0.925	0.920	0.070
Library	**CMGC**	4	**0.928**	0.995	0.138
	DBB	4	0.916	0.938	0.095
	Total	8	0.922	0.981	0.110
Office	CMGC	7	0.856	0.860	0.109
	DBB	2	**0.936**	0.936	0.091
	Total	9	0.874	0.871	0.106
Parking	CMGC	4	0.888	0.880	0.092
	DBB	3	**0.938**	0.967	0.082
	Total	7	0.909	0.920	0.085
Remodel	**CMGC**	35	**0.942**	0.990	0.081
	DBB	16	0.909	0.939	0.096
	Total	51	0.932	0.960	0.086
School	**CMGC**	23	**0.911**	0.920	0.080
	DBB	58	0.901	0.906	0.048
	Total	81	0.904	0.910	0.059
Sports Faciliti	CMGC	3	0.913	0.930	0.096
	DBB	2	**0.932**	0.932	0.077
	Total	5	0.921	0.930	0.079
Total	**CMGC**	111	0.925	0.950	0.086
	DBB	104	0.905	0.907	0.066
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 18: Results of DEA Scores by Project Type and PDS; note that bolding of the PDS by type indicates a higher average DEA score and light shading indicates that the difference in the average DEA score are greater than 5%

From the results in given in Table 18, it should be noted that the CM/GC PDS has a higher mean DEA score on six of the nine different project types, although none of these differences are statistically significant (principally because the N's are so small and the variances in the data so large). Hospitals show the greatest difference in DEA Scores with

CM/GC DEA scores 10.35% higher on average, but in the case of CM/GC projects, it's an average of one. DBB projects average about 8% better than CM/GC PDS projects on office buildings, but again, this is an average of only two projects, compared with seven CM/GC jobs. DBB projects achieved DEA scores 5% higher than CM/GC parking garage projects, and while these are nearly equal populations (3 DBB projects and 4 CM/GC), the difference between the two means is not significant. The three largest populations of projects were institutional projects with 25, remodel with 51, and schools with 81. CM/GC projects had higher mean DEA scores on all three of these project types than DBB: 4.05%, 3.28% and 1.0%, but again, none of these differences are statistically significant, and the practical significance of these differences is not great.

Another way to look at the DEA scores is to look at the number of efficient and near efficient projects (those with DEA scores > 95%) by project type and PDS. This data is captured in Table 19 below.

[illegible]	[illegible]	[illegible]	[illegible]
Corrections	8	1	9
Hospital	1	1	2
Institutional	7	5	12
Library	3	2	5
Office	1	1	2
Parking	1	2	3
Remodel	22	7	29
School	7	5	12
Sports Facilities	1	1	2
[illegible]	[illegible]	[illegible]	[illegible]

Table 19: Number of Projects with DEA Score > 95%

Here the difference between the CM/GC and DBB project scores is made more clear and is consistent with the non-parametric analysis results above. Note that most of the data are relatively close in comparison except in the case of Remodel and Corrections projects, where CM/GC dominates the DBB PDS performance. In schools, since there are so many DBB school projects (58 as compared to 23 CM/GC school jobs), the fact that there are more efficient and near efficient CM/GC projects is significant also (as well as counter intuitive.)[57]

4.3.2 DEA Model Weights

The weighting schemes used by each DMU to maximize their efficiency score are assumed to be an indication of how a project is managed. A project manager that puts a heavy emphasis on schedule performance as opposed to budget performance should result in a higher relative weight on the schedule as opposed to the budget metric. The intent of this analysis is to determine if CM/GC projects are managed significantly differently from DBB jobs.

Table 20 presents average virtual DMU weighting scheme given by the EMS software for the DEA model in order to maximize the particular DMU's technical efficiency score. Note these are averages of the weighting schemes given by project type and the total average for each PDS and are not the weight of any particular project, except in the case where only one project is a member of a particular project type.

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[57] As mentioned earlier, schools are the most common public building built in Oregon and elsewhere, as reflected in the Oregon data. Since there are more schools than any other type building one would expect that competitive bidding on schools would be fierce and that any problems in construction of this type would have been worked out, meaning little or no unknowns. Furthermore, since schools more or less have to open at the beginning of the school year, the opportunity for schedule growth is extremely limited. Of course, looking at it from the other side, perhaps those are reasons why the CM/GC projects have a higher average DEA score and higher proportion of efficient and near efficient projects. Fierce bidding reduces profits through winner's curse and errors, things that are not present in CM/GC. In addition, since the amount of knowledge and experience on schools is so broad and great, perhaps that allows CM/GC's to start even earlier and pay no cost in terms of performance.

An analysis of the DEA model input and output weightings gives some clues how the two populations maximized their DEA scores and made it to the production frontier (see discussion in [64] at page 25).

		DEA Model Inputs		DEA Model Outputs				
PDS	Project Type	Plans % Complete	SF/RFI+AR	SF/PL Out	SF/$K Out	Budget Out	Sched Out	Profit Out
CMGC	Corrections	0.945	0.055	0.082	0.003	0.571	0.156	0.189
	Hospital	1.000	0.000	0.000	0.011	0.000	0.989	0.000
	Institutional	0.890	0.110	0.035	0.009	0.711	0.168	0.077
	Library	0.864	0.136	0.008	0.448	0.271	0.034	0.240
	Office	0.971	0.029	0.024	0.011	0.683	0.227	0.054
	Parking	0.976	0.024	0.103	0.099	0.443	0.203	0.152
	Remodel	0.833	0.168	0.074	0.103	0.355	0.227	0.241
	School	0.948	0.052	0.005	0.097	0.357	0.485	0.056
	Sports Facilities	0.977	0.023	0.000	0.000	0.154	0.523	0.323
	Total	**0.897**	**0.103**	**0.045**	**0.091**	**0.445**	**0.270**	**0.149**
DBB	Corrections	0.996	0.004	0.002	0.093	0.656	0.197	0.051
	Hospital	0.964	0.036	0.000	0.000	0.644	0.000	0.356
	Institutional	0.931	0.069	0.000	0.110	0.596	0.252	0.043
	Library	0.969	0.031	0.001	0.103	0.876	0.000	0.020
	Office	0.993	0.007	0.000	0.003	0.243	0.258	0.498
	Parking	1.000	0.000	0.184	0.039	0.147	0.476	0.154
	Remodel	0.916	0.085	0.049	0.177	0.376	0.322	0.077
	School	0.977	0.023	0.017	0.068	0.432	0.472	0.011
	Sports Facilities	0.965	0.036	0.013	0.045	0.655	0.000	0.288
		0.962	**0.038**	**0.023**	**0.087**	**0.466**	**0.369**	**0.056**

Table 20: Model average weighting scheme by project type and PDS for inputs and outputs

The difference between the two populations is slight. The CM/GC projects placed a slightly lower weight on the "% complete of plans and specifications" input than the DBB projects did, which is perhaps indicative of the fact that the plans and specifications are generally incomplete and to a lower level of quality in the CM/GC projects than in the DBB jobs.

On the output side the differences are again generally slight. The DBB projects place a higher proportion of their weight on the schedule control metric than do the CM/GC projects, while the CM/GC projects place more weight on the profit output metric – but this may be due to the fact that few of the DBB projects reported "profit," whereas in most of the CM/GC projects, the fee was known.[58] Both methods place about the same weight on the budget control metric and total cost per square foot metric. CM/GC projects place a higher weight on the quality metric than the DBB jobs, but the difference is only 4.5% on average for CM/GC as compared to 2.3% for DBB.

One interesting difference is found in Hospital work, where CM/GC projects placed no weight on the cost control metric and nearly all (98.9%) on the schedule control metric, whereas the near opposite is true with the DBB projects, where all of the weight is distributed between budget control and profit maximization metrics and no weight is given to schedule control. However, it should be noted that this analysis is based on just one (1) CM/GC project and three (3) DBB jobs, meaning the result is probably an anomaly.

[58] The CM/GC jobs were mostly cost reimbursable jobs and therefore were audited, which often included the amount paid for fee. DBB projects on the other hand were not audited nor billed in the same manner. The only projects where the profit metric was known was in cases where the contractor provided it to us.

		DEA Model Inputs		DEA Model Outputs				
		Plans % Complete	SF/(RFI+AR) in %	SF/PL Out in %	SF/$K Out in %	Budget Out in %	Schedule Out in %	Profit Out in %
(CMGC-DBB)/CMGC WEIGHTS	Corrections	5	92	98	3010	15	-26	73
	Hospital	4	N	N	100	N	100	N
	Institution	5	37	100	-1130	16	-50	44
	Library	-12	77	88	77	-224	100	92
	Office	-2	76	-78	78	65	-14	-816
	Parking	-2	99	-78	61	67	-135	-1
	Remodel	-10	50	35	-72	-6	-41	68
	School	-3	55	-226	30	-21	3	80
	Sport Fac	1	-54	N	N	-325	100	11
	Combined	-7	63	50	-5	-36	36	63

Table 21: Percent difference of average weightings: CM/GC vs DBB

		DEA Model Inputs		DEA Model Outputs				
		Plans % Complete	SF/(RFI+AR) in %	SF/PL Out in %	SF/$K Out in %	Budget Out in %	Schedule Out in %	Profit Out in %
(CMGC-DBB)/CMGC WEIGHTS	Corrections	5	5	8	-9	-9	-4	14
	Hospital	4	-4	0	1	64	99	-36
	Institution	5	4	4	-10	12	-8	3
	Library	-11	10	1	34	-61	3	22
	Office	-2	2	2	1	44	-3	-44
	Parking	-2	2	-8	6	30	-27	0
	Remodel	-8	8	3	-7	-2	-9	16
	School	-3	3	-1	3	-7	1	4
	Sport Fac	1	-1	-1	-5	-50	52	4
	Combined	-7	7	2	0	-10	-10	9

Table 22: Absolute differences in average weightings: CM/GC-DBB

Table 21 and Table 22 present two different ways of looking at the different weighting schemes employed by the different PDS's. The percent different statistics can be somewhat misleading because they magnify what may actually be rather small differences, such as the 92% difference in corrections quality input metric (SF/(RFI+AR)) which is in fact only a 5.1% absolute difference. But overall, these statistics do point out some very important differences in weighting schemes, which we take to imply differences in management priorities. Project quality has a 63% higher weighting in CM/GC than DBB, which is consistent with the comments taken from the stakeholder analysis (see Chapter 5). CM/GC projects place a 36% lower weight on the schedule control metric than DBB projects do and a much higher (63%) weight on the profit maximization metric, but this is likely misleading as discussed above.

Lastly, a cluster analysis was performed using all of the weighting data from the DEA model to determine if the PDS were clustered by output metric. For example, did all of the CM/GC projects cluster into one group with a significantly different output weighting scheme than DBB projects did? For this analysis a K-means clustering method was used and three different clustering arrangements were specified: four clusters, three, and two.

	1	2	3	4
CMGC	22	38	18	33
DBB	9	59	10	26
	1	2	3	
CMGC	24	40	47	
DBB	12	63	29	
	1	2		
CMGC	62	49		
DBB	69	35		

Table 23: Cluster Membership by PDS

In all three clusterings, there is one cluster that places a high weight on the Budget Performance Metric and another cluster that places its highest weight on the Schedule Performance Metric. However, cluster membership does not appear to be related to PDS, except in rare situations. In the four cluster analysis, cluster 1 is dominated by CM/GC projects (more than 2:1), cluster 2 is dominated by DBB projects (about 3:2), and cluster 3 appears to be dominated by CM/GC projects (nearly 2:1). However, while there is a large difference between cluster 1 and cluster 2, with cluster 1 placing its highest weight on Budget Performance and cluster 2 placing its highest weight on Schedule Performance, there is no notable similarity between clusters 1 and 3, nor is there a large difference between the memberships by PDS of cluster 4. In the three cluster analysis, there is a significant difference between clusters 2 and 3. Cluster 2 is dominated by DBB projects and places its highest weight on the Schedule Performance Metric, whereas cluster 3 is dominated by CM/GC projects and places its highest weight on Budget Performance. The two cluster analysis indicates little difference between the memberships by PDS but follows the same pattern of weightings as the previous analyses.

It is possible to conclude that CM/GC projects are managed with a higher emphasis on budget performance than schedule performance and vice versa for DBB projects. This is consistent with the earlier analysis, but weakened by the fact that the major differences disappear in the two-cluster situation and a discriminate analysis of cluster membership by PDS was not significant.

4.3.3 Slacks

The other important question to ask is how could the inefficient DMUs actually improve? In linear programming models like DEA, the slacks tell us "the possible input excesses and output shortfalls" [64] at page 44, or in other words, areas where the project can improve in order to become efficient.

Table 24 below is a gross comparison of the means of the output slacks from the DEA model for the 159 inefficient projects by PDS.

Project Delivery System		Quality	Cost/SF	Cost Control	Profit	Schedule Control
CM/GC (N=70)	Mean	0.208	0.255	0.018	0.097	0.131
	Std. Deviation	0.386	0.364	0.098	0.151	0.265
DBB (N=89)	Mean	0.169	0.128	0.033	0.081	0.090
	Std. Deviation	0.149	0.210	0.149	0.131	0.226

Table 24: Statistical comparison of the DMU slacks

The data presented above gives us only a broad notion of perhaps how the projects on average can improve. Normally, the value of the DEA model is derived by evaluating the projects on an individual basis and determining how each individual project or groups of projects would have to improve in order to reach the efficiency frontier. For example, it would have been possible to break the projects down by construction company and let the management know if there are any trends in their projects that make them inefficient and suggest ways to improve them. However, in order to obtain project data for this research, complete confidentiality about the projects had to be granted (as detailed in Chapter 3), and therefore is not presented here.

One note of caution is that missing data in the outputs will have a significant effect on the slacks (for example, in the profit performance output metric). In general, both CM/GC and DBB projects show the least available improvement in the cost control metric and relatively high available improvement in quality and cost per square foot output metrics. But, the variances in the data are quite high relative to the mean in all categories. Lastly, it must be remembered that the slacks only occur in inefficient projects; the fact that a higher proportion of CM/GC projects are efficient, as compared to DBB, raises questions about whether or not this analysis can be generalized to the entire population of CM/GC projects.

4.3.4 Summary of the Interaction of PDS by Application

In answer to the third research question regarding the interaction of projects by project type and strategy of getting to the efficiency frontier, there is no significant difference between the PDS's. Neither PDS appears to be significantly out-performing the other on specific types of projects, nor does it appear the populations of projects use different management priorities or emphasis in order to reach the efficiency frontier, although there appears to be a weak relationship between CM/GC projects and budget control emphasis and DBB projects and schedule control emphasis. These differences in the weighting schemes used by the two populations of DMUs and differences in the efficiency scores of the different project types by PDS are marginal and do not appear to be statistically significant. In addition, only institutional, remodel, and school project types had sufficiently large numbers in both types to make the comparison particularly meaningful. This finding is unfortunate because one of the early goals of this research was to provide public agency building owners some guidance in making a PDS choice based on the type of project.

We fail to find sufficient evidence to support the hypotheses that CM/GC projects have higher mean technical efficiency scores than DBB projects for specific project types (the principal hypothesis H_{03} and each of the sub-hypotheses: $H_{03.1}$ to $H_{03.9}$). We find no basis for rejecting the null hypothesis that CM/GC does not outperform DBB projects of similar project type.

5 Surveys from Stakeholders

As has been noted throughout this dissertation, this research emphasizes the application of operations research and statistical models to evaluate a public policy in the public construction industry sector. The analysis of public policies in a complex environment simply cannot be limited to quantitative models, as Quade noted in 1982:

> "In public policy affairs, no matter what problem the analyst investigates there will always be aspects for which quantitative techniques are clearly inapplicable or inadequate. Sometimes, (but rarely) this is of little consequence ... a quantitative model, which may not include all aspects of the problem, may provide the analyst or decision-maker with sufficient insight for him to modify the results in the light of his additional knowledge about aspects that could not be incorporated into the model." "Policy analysis is critically dependent upon the use of [expert] judgment" [163].

This extended quote demonstrates that, in the realm of policy analysis, the role of expert opinion is often times a key ingredient in the final outcome. Furthermore, as Crowley [67] states, "there is a puzzling contrast between policy-makers and practitioners on the effectiveness of competitive procurements."

In order to better understand the PDS decision, that is, the choice to exempt or not exempt a specific project from competitive bidding, expert opinion of the practitioners was sought. In addition, we sought to uncover information that would either support or refute Crowley's supposition, that there are strong differences of opinions among project stakeholders. Finally, we sought to better understand and explain the different underlying attitudes of the stakeholders.

5.1 Research Question #4:

The fourth research question basically asks whether or not the opinions of practitioners, the actual persons that deal with projects on a daily basis, are consistent with the data analysis, and secondarily, if all of the practitioners' views are consistent with respect to project performance under the different PDS's?

5.1.1 Multiple Stakeholder Analysis

The idea of utilizing multiple perspectives in analysis dates to the 1950's with extensive contributions in the 1960's culminating in Linstone's 1984 book, *Multiple Perspectives in Decision Making* [142]. However, stakeholder analysis, as discussed by Harrison and St. John in *Strategic Management of Organizations and Stakeholders* [106], has generally been treated as an analysis tool to formulate business strategy that balances or optimizes the rewards (and penalties) to the various stakeholders. Here, we use the stakeholder analysis to better understand the PDS decision, and the different attitudes and perceptions of the project stakeholders with regard to the choice of PDS.

In the Washington study [99] the authors elicited comments from the different stakeholders in the projects as part of their analysis. The authors asked the participants to answer to provide comments and observations about the use of CM/GC[59] and to compare CM/GC with DBB on these public projects. The authors did not make an evaluation of the comments; however, they did put all of the comments arranged by commenter type: architect/engineer, contractor, owner, and subcontractor in their, "Appendix J."

[59] Or in their case "GC/CM or sometimes referred to as CM with a GMP" but they are equivalent PDS to CM/GC used in Oregon, and CM@R and CMR used in the CII Studies.

The analysis here generally follows the "Systematic Form for a Narrative Analysis" outlined by Manning and Cullum-Swan [144] with conclusions and evaluations made consistent with additional sections found in [73].

5.1.2 Project Stakeholders

In the construction industry, stakeholder analysis has been used as part of the TQM process. As noted by Kumaraswamy [130], its purpose is to recognize the "heightened need for effective and efficient evaluations by stakeholders... [to help] improve the management of ongoing and oncoming projects." Kumaraswamy lists the construction project stakeholders as owners, contractors and professional consultants and notes that the construction industry is currently lacking the type of systematic project evaluations proposed in [130].

In addition to owners, consultants and contractors, the subcontractor and supplier community along with the taxpayer could be considered as project stakeholders. Clearly, subcontractors have a stake in successful project outcomes since a bad project outcome inevitably reflects poorly on them as businesses (i.e.: poor quality) and a bad financial outcome might be passed on to them from the general contractor (i.e.: withholding retainage or progress payments). However, the enabling legislation that allows for the exemption from competitive public bidding requires that an exemption will not result in reducing competition or favoritism (see Section 2.6 above). This requirement has been taken by many public agencies to mean that all subcontracts are to be competitively bid. For this reason, the relationship between general contractor or CM/GC and their subcontractors is not fundamentally changed by the change in general contractor selection method.[60]

5.1.2.1 DBB Lump Sum Bid Selection Management Model

Figure 30 below depicts the management relationships typical of the lump sum bid selected construction project as presented by Eberwein [85].

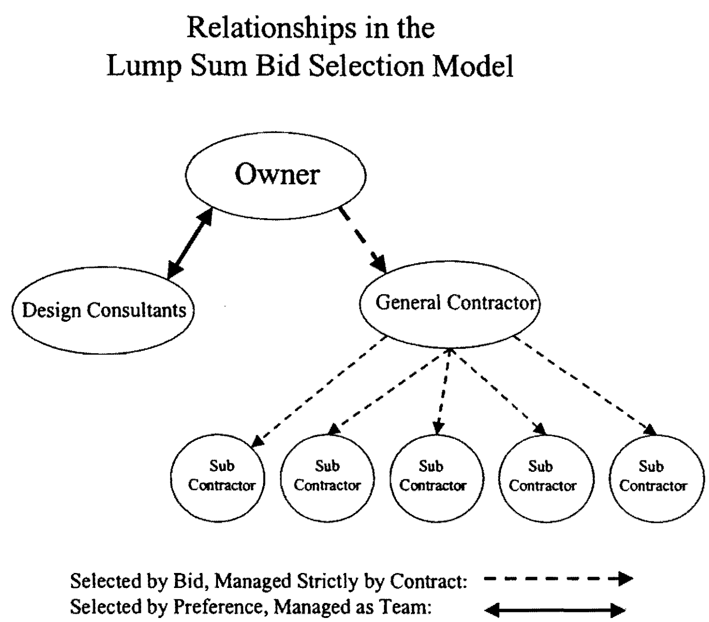

Figure 30: DBB or Lump Sum Bid Relationship Diagram

Note that in this model the owner and the design consultants form a team, while the general contractor and subcontractors are managed strictly by contract provisions. Furthermore, note that the relationship between the design consultant and the general contractor passes only through the owner. This is due to the "privity of contracting"

[60] Although some subcontractors may argue that the CM/GC method is actually more difficult for the subcontractor because the CM/GC acts as the owner's agent to deny subcontractor extra work claims since the CM/GC does not stand to benefit from the change order, particularly if it exceeds the GMP. This changes the CM/GC from an ally to an adversary.

requirements. The owner and the design consultants have a strong mutual relationship because the owner, by selecting the design consultant on the basis of preference as opposed to lowest bid, has a stake in the design consultant's success and vice versa. The relationship between the general contractor and the owner is much weaker on a personal level because the owner has less personal credibility at stake if the lowest bidder happens to fail in one way or another. That is, the decision to select the contractor was not entirely in the owner's hands because the lowest bidder is automatically selected.[61]

In the normal process, general contractors select subcontractors on the basis of lowest bid price in assembling their bid. This process results in relationships that are more often than not contractual as opposed to personal or team oriented.[62]

5.1.2.2 Non-bid (CM/GC) Selection Management Model

Figure 31 depicts the management model for the non-bid or CM/GC construction project as presented by Eberwein [85].

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[61] There are some pre-qualification requirements contractors must meet for bidding; however, these are minimal, and if a contractor is capable of obtaining a performance and payment bond, they are normally considered "qualified." Also, contractors can be disqualified post bid if they fail to meet various minority business utilization requirements on some contracts.

[62] General contractors have substantially more flexibility in selecting subcontractors in that there is not legal mandate that the general contractor must use the lowest sub contract bidder; it is simply a rational business decision to use the sum of the lowest sub prices when the general contractor is selected on the basis of lowest total price.

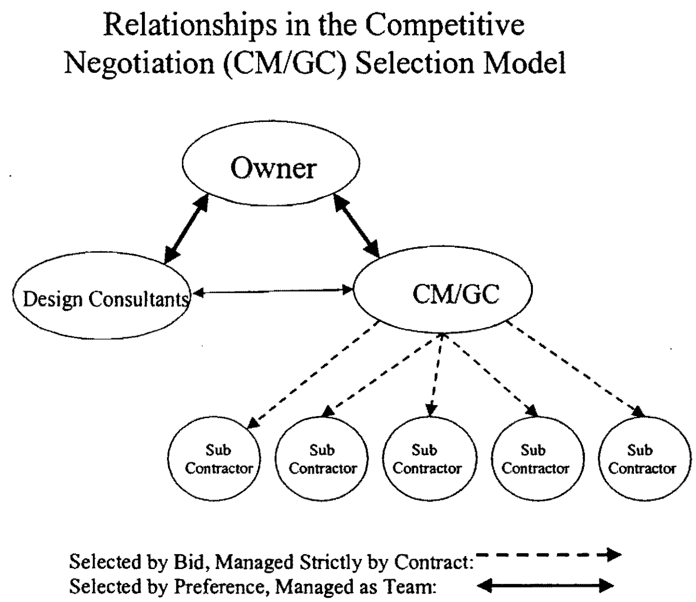

Figure 31: CM/GC Relationship Diagram

Note in this model the management relationship between the owner and the CM/GC is essentially the same as the relationship between the owner and the design consultant. This is because the method by which the CM/GC and the design consultants were selected is essentially the same. They are both selected on the basis of owner preference based on perceived qualifications for the job, among other considerations. Note also that there is now a direct "team management" relationship between the CM/GC and the design consultant. However, since the selection method for the subcontractors remains the same as in the lump sum model, the relationship between the general and subcontractors remains essentially the same. This analysis holds equally true for suppliers, perhaps even more so, because suppliers normally simply ship materials to a jobsite and receive payment through purchase orders, a practice common to both management models.

Since the fundamental relationship between the subcontractors and either a general contractor or CM/GC is essentially the same, we have decided not to include subcontractors in our stakeholder analysis. This is not to say that subcontractors and suppliers are not stakeholders in project outcomes; they certainly are, as discussed above. We are simply saying that since the relationship is the same in both models, we expect their view of efficiency would not be affected by selection method.

5.2 Goldblatt and Septelka [99] Stakeholder Analysis

Goldblatt and Septelka [99] asked stakeholders and competitors to provide their observations and comments about the use of CM/GC on public projects and to compare the PDS's in terms of project performance, project team performance, design, pre-construction services, subcontractor work-packages, project management, construction, commissioning and start-up, and acceptance and close-out. They also asked competitors, both contractors and subcontractors presumably who did not work on projects, to provide comments. Finally, they invited the Agencies to provide "Project Evaluation Survey Comments" on: Schedule, Cost, Changes, Quality, and Process Evaluation.

5.2.1 Team Survey Comments

The project teams, including the CM/GC, the architect/engineer, owner and subcontractors were asked to comment on the project performance and compare the CM/GC process on the particular project that they were working on. The comments by the CM/GC, the owner and the architect/engineer were generally positive observations with some caveats such as:

- Subcontractors have performed well in dealing with tough remodel conditions. The change order prices are at a premium.
- Met & exceeded a very aggressive schedule while delivering a high quality product. Cost was appropriate to the product value.
- The design took longer than expected; however, we are on track for an early building delivery.
- Good project except for warranty issues.
- The resulting building has received an AIA Honor Award, as well as others. User satisfaction is very high. Process to get there was very difficult and painful.
- Very good input from the [CM/GC] RE: Cost, Schedule, and Constructability.

Subcontractors had distinctly different observations:

- Unreasonable and inflexible schedule drove cost increases. Lack of CM/GC self-performing significant portions of the work themselves caused a disconnect between the CM/GC and the project schedule.
- Poor CM/GC performance. Withholds information. Slow to respond to RFI's and change orders.
- For a variety of reasons, the build-out was delayed 6 months with the completion date remaining unchanged. The compression created significant impacts given 250 electrical changes & 2500 RFI's.

In comparing the PDS's directly, again the architect/engineers (A/E), contractors (C) and owners (O) comments were generally positive and in favor of CM/GC. A sample of the comments by commenter type are given below:

- A/E: Project proceeded more smoothly with [CM/GC] leadership as agent for the owner.
- A/E: Performance was accomplished with less conflict than in DBB.
- A/E: The [CM/GC] contractor has been only "slightly" more of a partner in problem solving for design problems than with a DBB contract.

- C: There was considerable project savings.
- C: [CM/GC] process provided the owner better control of the program components at a lower cost than a similar DBB.
- C: WSU had many bad DBB experiences and opted for [CM/GC]. It was a wise choice – project has been a resounding success.
- C: This project was completed on time, within budget, and without claims, which likely would not have happened under the traditional DBB process.
- O: Better construction documents, no surprises and better team attitude on the side of the contractor.
- O: It is very difficult to separate cost and schedule problems into those resulting from conditions at the time of project, and those resulting from [CM/GC] methods.
- O: Reduced Claims by subs.
- O: [CM/GC] process has no vested ownership except $, they sided with the subs on all disputed issues.
- O: The performance of the [CM/GC] on this project is far superior to that on any other DBB project with which I've been involved.
- O: [CM/GC] cost management between design phases (estimates) yield better cost control of project.
- O: Higher level of cooperation among team members. Changes made with less impact. Better quality.

There was only one subcontractor comment listed:

- [CM/GC] offers the subcontractor no control in comparison to DBB. Job stagnated due to multitude of RFI's/changes. [CM/GC] removes subcontractor from direct contact with the owner.

On Team Performance, again the architect/engineer, contractor, and owner comments were generally positive, while the subcontractor comments were generally negative. It is clear from the comments that the owner-contractor-architect/engineer relationship in CM/GC is considered improved over the DBB process. Each of these construction team members commented that the "relationships have been good and positive," "very collaborative / trusting," "Team worked very well together," "Excellent." There were a couple of isolated negative comments:

- A/E: Owner's representative was too weak.
- O: Partnering process was incomplete and virtually abandoned.
- O: Biggest problem was lack of mechanical/electrical design coordination.

Subcontractor responses, which include only three (3), were not as positive:

- Overly aggressive design period and incomplete project programming prevented complete design prior to construction phase. This contributed to cost overruns.
- [CM/GC] and A/E were poor performers; slow to respond; avoided problem resolution.
- Performance suffered from magnitude of design deficiencies. [CM/GC] had limited experience with several key personnel. Job tended to move on its "mass" as opposed to positive schedule directions.

The survey in [99] goes on and elicits comments regarding Design, Project Management, MACC Negotiations,[63] Pre-construction Services, [CM/GC] Selection Process, Subcontractor Work-packages, and other topics. The responses under these topics are consistent with those discussed above. Architect/engineers, contractors and owners are generally positive with a very few negative comments and caveats, and the Subcontractor comments, which are few by contrast, are generally negative with a few positive notes.

[63] MACC is Maximum Allowable Construction Costs – a process that is solely part of the negotiated contract and does not pertain to DBB.

One area that [99] was able to look at that this research did not, was a survey of disappointed competitors. While these comments, sixteen (16) in all, and equally distributed between general contractors and subcontractors, make up only one of the 18 pages of comments, they do provide an interesting insight to the process by those who were unsuccessful in obtaining CM/GC work or, in the case of subcontractors, work on the CM/GC jobs. (Comments are preceded by "C" and "S" for contractor and subcontractor.)

- C: This selection process was still based on a low fee proposal as opposed to including qualifications and interview as part of the selection process. The current law and selection process is much better.
- C: The owner selected an out-of-region contractor who has performed poorly and jeopardized the [CM/GC] process for this owner.
- C: The delivery method is proven. Your process of applying this method restricts you from greater value. Your rigid RFP limits creativity and forces us back into the box.
- C: You're more concerned about past similar experience than the best team & the best ideas.
- C: [CM/GC] submitted a very low fee/GC proposal, which moved them from last to 1st in the ranking and got them the job!
- S: The drawings were so convoluted we could not tell what we were bidding for and what was by others. On top of that, State General Conditions [CM/GC] have many more requirements that just make it harder to comply. They would like to do all the work themselves.
- S: [We] did not pre-qualify because of [a] technicality (no shop drawing sample with proposal) and we were later told they had too many applicants.
- S: Project was bid with no solicitation process. Only contractors that qualified for Phase 1 were allowed to bid on Phase 2.
- S: Pre-qualification was largely based on sales volume and having performed much larger projects than this project. Eliminated free

competition to small & mid size contractors who have had proven success in project of this magnitude.

In summary, it is clear from the comments in [99] that the process in Washington state has a lot of supporters, particularly among the ranks of the successful CM/GC contractors, owners and architect/engineers. Subcontractors, on the other hand, both those who worked on the projects and the disappointed bidders, revealed some of the shortcomings of the process as it's practiced in Washington. This would likely be true of any new process; however, and is probably not limited just to CM/GC. However, as discussed in above, it may be difficult to get an honest and objective set of comments when the vast majority of the respondents either are personally invested in the decision to use one PDS over another, and the others are the beneficiaries, the successful contractors. The comments from the disappointed contractors and those from the architect/engineers reveal more skepticism about the process than the owners and the successful contractors did.

5.3 Stakeholder Survey

For this research, it was determined that the stakeholders and construction professionals should be asked specific questions regarding the different PDS's, the benefits and drawbacks, and to whom they accrue. The different stakeholders were given the following questions to consider, in the order found in the following Table.

Please describe, in your own words, the benefits of the negotiated public contracting project delivery system, commonly known as CM/GC for the contractor, the owner, the design professional, and the public at large? Benefits for the contractor: Benefits for the project owner: Benefits for the project design professionals: Benefits for the public at large: Please describe, in your own words, the drawbacks of the negotiated public contracting project delivery system, commonly known as CM/GC for the contractor, the owner, the design professional, and the public at large? Drawbacks for the contractor: Drawbacks for the project owner: Drawbacks for the project design professionals: Drawbacks for the public at large: Please describe, in your own words, the benefits of the competitive bid public contracting project delivery system, commonly known as Lump Sum Bid Method, for the contractor, the owner, the design professional, and the public at large? Benefits for the contractor: Benefits for the project owner: Benefits for the project design professionals: Benefits for the public at large: Please describe, in your own words, the drawbacks of the competitive bid public contracting project delivery system, commonly known as Lump Sum Bid Method, for the contractor, the owner, the design professional, and the public at large? Drawbacks for the contractor: Drawbacks for the project owner: Drawbacks for the project design professionals: Drawbacks for the public at large:

Table 25: Stakeholder Survey Form, which was originally published on eight pages, shown here with blank sections removed for brevity.

This method could not be described as a "scientific" survey because a broad cross-section of stakeholders was not surveyed; only those members of project teams who provided project data were asked initially to respond. Additional contacts were made through the Oregon Public Contractor's Coalition (PCC) as well as members of the Expert Panel. Finally, professional associates, many of them members of the Oregon Construction Bar, were asked to give their comments on these questions and their observations on the two PDS's. In all just under five-hundred individual comments from 21 stakeholders were recorded. And, while this research instrument was structured differently than the one used in [99], no claim is made here that these responses are better considered or carry more weight.

5.4 Stakeholders

The principal stakeholders in the public construction sector of the economy are the contractors that build the jobs, the design professionals that prepare the plans and specifications, the public agency project team that manage the project from womb to tomb (referred to here as "owner") and the public at large who eventually use the project. Three of these members are readily identifiable by the roles that they have on a project, but the fourth, the public in general, is a bit more difficult to identify. In absence of a broad survey of building users or the public, this research considers the guardians of public trust, the "owner," as the adequate proxy for the concerns of the "public at large." It should be realized that the project management staff may not always have what's best for the taxpayer or public at large first and foremost in their minds, especially when what's best for the taxpayer may not be what's easiest or most convenient for themselves in the management of the project in pursuit of its completion, and keeping as much "stomach lining" as possible at the end of the project.

A group that is neither a proxy for the public nor a direct project participant, but one included in this analysis, is the members of the Construction Law Bar of Oregon. These attorneys handle the vast majority of construction disputes that rise to the level of third-party negotiation, mediation, arbitration and litigation. Their insight was considered valuable information to include in this section of the research.

5.4.1 Contractors

Contractors are perhaps the most affected members of the project team by the choice of PDS on the project because that defines the roles and risks the contractor must execute the project under. Contractors make up the largest number of the comments in this survey; roughly 44% of all comments were contractor comments.

As documented in Chapter 3 above, contractors on the Expert Panel were the first to be contacted in the data collection effort. Included in their data collection Notebooks was "Tab 6 – Written Comments" that contained the questions listed exactly as they appear above.[64] This is the principal reason that contractors provided the largest number of comments. Of course, contractors also have the most experience in the different PDS's since their jobs involve the construction of public building projects on a daily basis. Furthermore, unlike owners and design professionals, contractors, in particular estimators, see many projects each year that they bid on but do not "win." This gives the contractor a

[64] Although the survey form presented above has been edited to remove the empty spaces between the individual questions, the original Tab 6 – Written Comments was eight pages long.

distinctly different viewpoint than either the owner or the designer. In addition, of course, the contractor is in business to make money on construction work, period. The beauty of the job may be pleasing, but the construction project manager and superintendent that consistently build high quality, beautiful projects that lose their companies large sums of money, generally find themselves not working in the business long. Conversely, the superintendent that consistently returns large job profits on marginal quality work is likely to be retained.

Construction is a risky business with total fees on sales to the general contractor in the range of two and one-half to five percent (2.5% to 5%), which is among the lowest of any business sector. However, the fact is that while the general contractor on building projects has a substantial risk of subcontractor performance, much of that risk is laid off on the surety industry. The total amount of actual performance risk a general contractor has on a project is typically only about ten percent (10%) of the total project cost, which means that the general contractor's fee is more in the range of twenty-five to fifty percent (25% to 50%) of their direct work. Furthermore, the subcontractors that account for about ninety percent of the actual work performed are also in business to make a profit, and their fees range from five to fifty percent (5% to 50%) of their total subcontract bid cost. This means that the total amount of fee derived from a construction project to all parties is more in the range of thirty percent (30%), which is more in line with other service industries. Nevertheless, as businesses go, few have the potential for such large gains or windfall profits and extreme bankrupting losses on a single endeavor as construction contractors face on virtually every job. Contractors bring to the construction team the understanding of how a project actually gets built and what kinds of sacrifices and trade-offs have to be made along the way to make it happen. As a group, it is fair to say that contractors see themselves as protecting the public interest against wasteful design solutions brought by design professionals that have little or none of the practical building experience that comes from actually building a project. Even in the competitive bid market where contractor/owner relationships are more confrontational and adversarial contractors probably complain more about wasteful design solutions that make their job harder for no visible benefit than they do about the unfairness of an owner's position on the design issue or decision about the cost.

The part of the construction business that is the subject of this research, namely large building construction, attracts a group of individuals that are very bright, imaginative, highly motivated people that are extremely hard workers, fiercely competitive and almost bluntly self reliant. In the competitive bid market, they compete in a remarkably pure form of economic competition in the US economy, a market where an owner puts a project up for a sealed price auction and the competitors, each acquiring symmetric information about the task, weigh the risks and rewards and gives a price. And, in absence of some form of gerrymandering the bid, the lowest price bidder takes the prize. The construction project managers, estimators and company executives that responded to the survey for this research have built literally billions of dollars in public construction between them. Their experience is vast and deep and without their contributions to this research, it simply would not have been possible.

5.4.2 Owners

Owner's representatives are the agents of the public charged with the public trust and responsible for spending the public's taxes wisely. They initiate the projects, hire the design professionals, guide the process through design into construction, manage the construction process, pay the design professionals and the contractors, and finally occupy the end product – the building. Often, the owner's representative is even involved in the financing or procuring of funds through bond sales or other forms of public finance.

Owners may have a difficult time relating to other stakeholders, but they know that building projects cannot be accomplished without the teamwork of all three construction partners. It is the owner who decides on how that working relationship will be structured through the choice in PDS, and therefore understanding the motivations and feelings of the ones who make that decision is an important contribution to the understanding of why and how that decision is made.

As with the contractor group, the initial contact of owners was through the expert panel members. That effort extended when the data collection phase included directly retrieving information from the owner document files at the different institutions. The majority of the owner comments come from expert panel members or senior project management personnel, in particular those directly involved in making the PDS decision.

5.4.3 Design Professionals

Architects and engineers play a key role in the execution of any public building project. Architects prepare the information upon which the pricing for the project is based. They more often than not follow the project from design through construction, inspecting the construction professional's work and advising the owner on change requests and pricing submitted by the contractor. The contractor too has to rely on the architect for design solutions for unanticipated and hidden conditions as well as a fair interpretation of the plans and specifications when a change request is submitted. In the most recent version of the General Conditions prepared by the American Institute of Architects (AIA), AIA form 201, the role of the project architect is so important that the owner cannot summarily dismiss and replace the architect without the prior acceptance of the contractor.

The design professional respondents predominantly come from the expert panel, which includes partners in many of the largest architecture and engineering firms in Oregon. Most have extensive experience in both PDS's being considered in this research and are often called upon by owners to give their opinion on which method should be used in the performance of a particular project. Furthermore, several served in the past on the selection committees that selected CM/GC's for specific projects that they may or may not have had direct responsibility for.

5.4.4 Attorneys

One group that was not originally considered in the Stakeholder Analysis Proposal was the members of the Construction Bar in Oregon. Construction law is a very specialized field with fewer than one hundred fifty (150) active members,[65] the majority of whom work for one of fewer than two-dozen firms, mostly located in Portland. The members of the Construction Bar are not actively involved in the direct execution of construction work, except as it may relate to specific contract provisions that they may be

[65] Which, compares to the more than 1000 members of the Tort Law Bar in Oregon.

asked to opine upon. However, these professionals have a unique role in the construction process in that they are involved in mediating, arbitrating and litigating construction disputes. From that vantage point, they witness what kinds of things go well, and more importantly, what kinds of things don't.

The lawyers that responded to this survey serve owners, contractors and subcontractor clients. Most practices emphasize one or another type of client, but very few if any only take "owners" or "contractors" as clients, and each of the respondents in this survey has served or serves each of the three parties. That fact makes them uniquely qualified to comment on the impact of different contract structures on various parties.

Finally, while attorneys are advocates for their clients' position, like engineers, their duty extends beyond that owed to their particular client, to the Court and the public at large. Attorneys accounted for a total of 61 individual comments, with benefits outnumbering drawbacks 38 to 23. Since attorneys are perhaps the least directly affected by the use of one PDS or another, it is likely that, as a group, they provide the most objective observations,[66] although it should be noted that three of the attorney respondents worked directly for an owner or a contractor as either an in-house counsel or a project manager.

[66] Although at least one contractor Stakeholder would disagree, noting that if CM/GC reduces claims, lawyers are out of work, which is a valid point. However, it is actually quite rare that construction disputes actually go so far as trial;, as many as 95% of all construction disputes are settled in negotiation or mediation according to one prominent mediator. And, while the CM/GC – owner relationship changes, the CM/GC – subcontractor relationship is changed little from the DBB model. The OSU Valley Library Project discussed above, for example, was a multi-million dollar claim brought by a subcontractor against both the CM/GC and the owner. Nevertheless, the point is well taken.

5.5 Responses

There were 499 individual responses from the stakeholders, although at least three of the responses from one owner were word for word the same for three of the four beneficiaries. The breakdown of the comments is reflected in the following table:

Stakeholder	Benefit/ Drawback	CM/GC	DBB	Total
Attorney	Benefits	25	13	38
	Drawbacks	13	10	23
Attorney Total		***38***	***23***	***61***
Contractor	Benefits	108	30	138
	Drawbacks	34	49	83
Contractor Total		***142***	***79***	***221***
Design Professional	Benefits	28	17	45
	Drawbacks	24	19	43
Design Professional Total		***52***	***36***	***88***
Owner	Benefits	58	21	79
	Drawbacks	21	29	50
Owner Total		***79***	***50***	***129***
Grand Total		**311**	**188**	**499**

Figure 32: Stakeholder Survey Responses

The most striking observation is that contractor comments reflected benefits from CM/GC more than three-to-one over drawbacks, while indicating drawbacks to DBB nearly five-to-three over benefits. While all of the Stakeholder groups had more benefit than drawback comments for CM/GC, and more drawback than benefit comments for DBB, no other group showed such a striking difference. In part, this was due to the fact that several of the contractors simply refused to comment on drawbacks to CM/GC, perhaps feeling that their comments could come back and be used against them or the process. Some contractors also decided not to provide any benefit comments under DBB. These actions call into question the objectivity of the respondents; however, their comments still have importance because they allow us to understand the motivations and mindset of these participants.

5.5.1 Contractor Responses

All of the contractors have experience in CM/GC, some more than others; however, all of the largest CM/GC contractors in this study did provide responses to this survey. Thirty of the one hundred eight (108) noted that the benefits of CM/GC were benefits that accrue to the "contractor," and contractors contributed two hundred twenty one (221) of the nearly five hundred comments in this survey.

5.5.1.1 Contractor's Perceived Benefits of CM/GC

The majority of the benefit comments from contractor respondents deal with risk and the contractor's ability to mitigate his risk by having significant input during the design process as well as gaining a better understanding of the project before the budget and schedule are established. One commented that, "basically risk is shared with the owner." There are also administrative and financial benefits accruing to the contractor on the cost reimbursable form. In spite of the fact that the overall profit is expected to be lower, there is a greater assurance that the profit goal will be met and that they can count on an adequate level of administrative support.

The relationship between the parties is another benefit that contractors felt accrued to themselves from the CM/GC PDS. "It makes the whole construction process a team effort." "The potential or opportunity to develop a good working relationship with the owner and designer." And "Less chance of adversarial relations … more stomach lining [left] at the end of the job."

Contractors generally responded that design professionals benefited from the CM/GC process by having the contractor's input during the design stages. They commented that, "construction professional input [resulted in more] cost effective construction," and that they aid design professionals in coming up with "more realistic schedule milestones" and "cost estimates." The contractors felt that CM/GC "reduces or eliminates redesign efforts" and costs, and results in a "far better working relationship," which is a benefit to the design professional. Contractors responded that the "reduced risk" generates "increased profit potential" for design professionals through mechanisms as an "independent design review" of their work by the CM/GC.

In short, as with the benefits accruing contractors, the contractors responded that the same apparatus that reduces risk and results in better working relationships benefit design professionals in similar ways. The one difference, of course, is the fact that contractors did not see design professional's input in CM/GC as a benefit to contractors, but they consistently remarked that their input during design was a benefit to the design professionals.

Contractors commented that owners benefit from CM/GC principally by reduction in the risk of claims and lawsuits; faster construction schedules; better designs through contractor involvement; "reduced conflict;" more reliability on costs and schedules; "lower fees" and lower overall costs.

Of course, the data analysis performed in Chapter 4 of this research does not support their comments that CM/GC results in more reliable costs or schedules than DBB, and competitive bidding theory dictates that a single competitor will result in higher, not lower, costs. There is little doubt that the relationship between the owner and CM/GC is far better than the typical owner – DBB contractor relationship, and contractors consistently commented that the change in relationship results in a higher likelihood of a "successful project." In addition, the cooperative process allows for and generates "improve[d] opportunity for a lower cost of construction on larger or more complex contracts." While the early input from the CM/GC gives the owner, "the benefit of an experienced and practical mindset in the development of the design, i.e. function leading form" and "the overall opportunity for a better design …[resulting from] the availability of a practiced eye, In the review of design documents [that] provide for the opportunity to reduce errors or inconsistencies in the drawings, catching mistakes on paper rather than in the field." Finally, the CM/GC "can use their skills and experience to advise the owner and architect as to the cost and efficiency of a project design at the time when those ideas can be incorporated most easily and cheaply" thereby providing for the most efficient use of limited public funds.

Contractor's comments on the benefits to the public in general mirrored those of the owners and design professionals but elicited the fewest total number of comments from the contractors. Contractors generally commented that the public benefits when the project team relationship is improved, in that projects are delivered with "less risk for delays [and] claims," and they "receive better accountability through open book methods of contract administration[67]" and "better use of taxpayer dollars."

One extended comment from a contractor questioned the premise of the question:

> If one is willing to take the broad view and consider the public at large as the "owner" of Public Works projects, then it would seem logical that the benefits to the owner section could conceivably be duplicated here. Outside of the broad view, the issue of a potential increase in quality, value, schedule, etc., may have a direct impact on the public. This would be in the form of quicker access to, use of, and/or enjoyment of a public facility, highway, etc. Aside from this "potential" I see little benefit to the public at large.

But generally it is fair to conclude that contractors felt that the public benefits from lower risk and "enhanced potential for project productivity" creating lower construction costs.

5.5.1.2 Contractor's Perceived Drawbacks of CM/GC

While contractor's felt there were a lot of benefits of CM/GC, they provided far fewer comments regarding drawbacks. While there were thirty (30) benefits to contractor comments, there were only thirteen (13) drawbacks accruing to contractor comments. Most of the drawback to the contractor comments reflected the lower fees derived from CM/GC contracts and complaints and frustrations about the non-level playing field of competition. The following comments are examples of the latter:

[67] However, Section 2 of this research documents the Audits Division of the Oregon Secretary of State's office audit of several CM/GC prison projects and their conclusion does not appear to support the claim of better accountability. Further, it should be noted that the model contracting rules (see Oregon Administrative Rules 137-30) requires an auditing provision on all public contracts, which is mirrored in most agency construction contracts.

- First, foremost and generally likely is the potential for abuse. The misuse of the CM/GC delivery method as a means of getting around fair solicitation practices hurts all but a very few privileged contractors.
- The contractors with little or no experience in the process have very few options in the way that they can develop the necessary experience to compete in the CM/GC RFQ/RFP solicitation process. It's the old Catch 22: one needs the experience to get the projects, yet needs the projects to gain the experience. Unlike bonding capacity, it is very difficult to grow into qualifying requirements necessary to compete.
- CM/GC projects tend to cherry pick the larger, more desirable projects out of the general marketplace.
- The success of CM/GC for the contractor depends upon the skills of the personnel the contractor has assigned to the project. They are different skills than a design-bid-build contractor uses to make money.
- Difficult to impossible to penetrate existing relationships i.e. [CONTRACTOR NAME] and the Port of Portland and Justice System.
- Harder for the smaller, newer contractor to obtain work.
- Contractors must develop staff resources and knowledge of CM/GC to be competitive for public CM/GC contracts.

While generally positive about CM/GC, contractors do acknowledge its drawbacks, particularly on smaller and up and coming contractors and their ability to obtain negotiated work in competition with the more established firms. In addition, there has to be a change in attitude that is difficult for some project team members to assume, to "shift to [an] owner first mentality." Further, in order to compete successfully, the CM/GC has to devote more time and money to "marketing," and those who depended solely on the competitive bid market in the early years of the CM/GC implementation saw fewer jobs coming their way.[68] This increase, and in some cases start-up of marketing department costs, is an added "overhead" cost that must be paid from construction fees, thereby reducing the aggregate profit of the organization.

Contractors made few comments regarding drawbacks to design professionals, and some of the comments on the surface do not appear to be drawbacks, for example, "allows fast track construction at the public level" and "allows contractors to influence design with cost schedule issues." Why contractors considered these to be drawbacks to the design professional is not clear. Also, the comment that "the architect is no longer working in a vacuum; the contractor is looking over its shoulder and this sometimes annoys some architects" is directly in conflict with the comment that the team approach alleviates much of the project animosities.

Contractors also commented, "I've never known any [drawbacks], ask an architect" but added from the contractor perspective, "Not sure there are any." And finally this:

> The drawback for design professionals may have some dependency on the ethical nature and/or the quality of the firm and the construction savvy or sophistication of the owner. A less than higher quality firm, which might normally have little concern of performing QC work and being paid directly by the owner. Aside from that anomaly the process should only benefit a design professional.

[68] Note that there was a substantial concentration of early CM/GC awards to one contractor. On the order of 19 of the first 21 projects were awarded to one general contractor who probably had the most established marketing apparatus in place because they competed in both the public bid and private negotiated construction markets. The shift to negotiated public construction contracts played directly into their strategic strengths, which resulted in capturing the lion's share of the market in the early years. This changed as other contractor developed better marketing skills and the market matured to where it is today with more broadly distributed awards.

This essentially means that the drawbacks to the design professional may be outside the PDS itself, but are rooted in the owner, architect and contractor's failings, irrespective of the PDS.

5.5.1.3 Contractor's Perceived Benefits of DBB Contracting

Contractors seem to comment that the benefits of DBB contracting are primarily financial because of reduced administrative costs, "Marketing department not required" and "opportunity for maximum profit." It's "easier to acquire work" but the work "may not be profitable." It's easier for a contractor to penetrate new and different markets and easier for "newer contractors to get work." It may be easier to motivate personnel to perform because they "can be profit oriented" as opposed to "owner first."

Good DBB contractors with well trained personnel can successfully execute work under DBB, and on occasion DBB is the best PDS for both the contractor, its subcontractors and the owner, as the following comments attest:

- By a clean record of good performance and financial stability, a contractor can grow bonding capacity and therefore increase overall number and dollar size of the projects they can go after and complete for. While some of the "Catch 22" problems exist here too, it is not quite as insurmountable.
- Lump sum bid or design-bid-build (DBB) is generally best understood by both the public contracting entities and the construction industry, has the strictest rules and remedies for all in the event of a failure of any party to adhere to those rules. For these reasons, it is therefore less likely to be abused.
- Skills in construction management, fair treatment of subcontractors, good record of performance and stability leading to lower bonding costs all provide a "good" contractor with legitimate means of gaining a competitive edge.

Contractors see fewer benefits of DBB accruing to design professionals, with only five comments and one of those being "?" And another that "Some design professionals will like to not have to include the contractor in the pre-construction phase (they are short sighted, of course)" are probably honest and maybe even true, but seem kind of mean-spirited.

Ultimately contractors view CM/GC as providing design professionals with more benefits, but they do comment that the "old tried and true project delivery system" that is understood well by most parties, and the freedom to assert "more control over the design processes," are benefits of the DBB PDS that accrue to the design professionals.

Contractors disagree on benefits to the owner, one stating that "I don't see any. The only one I have heard 'floated' is the certainty of the bid price, with which I vehemently disagree. Change orders on a bid job can hurt an agency budget badly." Others comment that DBB "insures the greatest [amount of] competition" and "depending on the design," results in "the cheapest price available."

According to contractors, the benefits that accrue to the owner are the same as those that accrue to the public in general. In fact, of the six comments provided by contractors, one is word for word the same and all but one, that there is "less potential for the perception of unfairness in the public works arena," which was not mentioned with regard to owners, are similar.

5.5.1.4 Contractor's Perceived Drawbacks of DBB Contracting

While it is fair to say that the drawbacks to DBB Contracting that accrue to the contractor are principally the opposite of the benefits that accrue under CM/GC, the lack of a cooperative and team-oriented relationship stands out. The competitive bid award that creates the adversarial relationship can be blamed for virtually every drawback comment that contractors raised:

- "Increased" and "very high risk"
- Creates owner's rep and the architect/engineer as decided adversaries
- Lack of repeat business objective
- All parties in an adversarial position (protect [your] own turf)
- The amount of fires increase
- Bad jobs get worse

Not explained, of course, is that DBB "must" create or result in an adversarial relationship – which is not necessarily true[69], but if one does assume it to be the case, a logical explanation of how and why should have been forthcoming. Conversely, it is not necessarily the case that CM/GC completely eliminates the possibility of an adversarial relationship, but admittedly, project professionals report that it happens a lot less often, but as seen in [99], some of the owners commented that the relationship was little changed from DBB.

5.5.2 Owners

Project owners accounted for 129 of the 499 responses, or nearly 26%. These included 79 on CM/GC (58 of which were benefits) and 50 on DBB (29 of which were drawbacks).

[69] Much literature has been devoted to the concept of "Partnering" as a method of reducing adversarial relationships on projects [96].

5.5.2.1 Owner's Perceived Benefits of CM/GC

Owners clearly see the greatest benefit of the CM/GC PDS accruing to the contractor, principally through the reduction of risk and "working in a cooperative team atmosphere." Risk is further reduced by the "opportunity to fully understand the job before committing to a GMP."

Design professionals, according to owners, benefit from CM/GC through lowered risk of claims (perhaps owing to the fact that the CM/GC better understands the contract documents and works with designer during their part of the preparation, therefore the chance of a misunderstanding of the contract requirements is reduced, which in turn reduces the possibility of claims).

Owners see themselves and the public in general to be the biggest beneficiary from CM/GC PDS, but are split on some specifics. These comments are examples:

- Requires less sophisticated staff by owner if architect/engineer is used to administer the construction contract.
- Contractor can sacrifice quality and schedule for profit if owner does not have sufficient resources or knowledge to provide administration and quality control.
- Contractor can make additional profits through change orders if the drawings and specifications are poor quality and the owner is not knowledgeable.

And these regarding the working relationship on the job:

- This process almost always creates an adversarial relationship with the contractor since his objective is to maximize profits and the owner's objective is to minimize costs.
- Team approach in completing project

And these regarding the types of projects it should be used on:

- Works best on small projects, less technically complex projects...
- Contracting method to deal fairly with complex projects having significant unknowns (for example: remodels/seismic upgrades).

And finally on Cost:

- Ensures the public the lowest cost project ...
- CM/GC results in a lower overall price ...
- This process does not necessarily guarantee the lowest life-cycle cost or the best quality project for the cost.

In fact, it appears that some of the respondents were confused about which question they were answering, particularly in light of the fact that they appeared to "cut and paste" in the same answers to different questions, in some cases both benefits and drawbacks of the same PDS.

At least one owner forthrightly stated that CM/GC allowed the "opportunity to choose the contractor" that the agency wanted and exclude contractors they didn't want to use. (Two others made similar but less pointed statements regarding choice of contractor.) It was clearly not the intent of the exemption clause to allow the public agency owner the ability to exclude contractors on public projects, but the possibility certainly exists whenever such latitude is afforded "less-than-perfect" human beings. In order to avert such an abuse of discretion, agencies generally have adopted policies governing selections, but these policies are in no way uniform nor are they statutorily required. And, instead of tightening up the statutory scheme, the legislature in Oregon enacted more sweeping exemptions for its university system and Oregon Health & Sciences University.[70]

5.5.2.2 Owner's Perceived Drawbacks of CM/GC

Owners remarked that contractor's only drawbacks resulting from CM/GC are the additional financial burdens of "lots of up-front marketing," taking more time to complete the job (due perhaps to extensive pre-construction services period), and the inability to "strike it rich" on a given job.

Owners see few drawbacks accruing to design professionals, except that they have to surrender some of their "pride of ownership in the design" to the team, and that they "have to deal with the contractor's comments [and] opinions." For the owner and the public in general, owners seem to agree that the process "could cost more up front," and that the process "takes longer [and] professional fees are higher" and "may cost a little more than a hard bid job." Another drawback is the fact that there is no clear objective winner in the selection process and that the "selection process may be viewed as biased by some contractors calling into questions ethics and public administration." But others saw no drawbacks to the use of CM/GC PDS.

5.5.2.3 Owner's Perceived Benefits of DBB Contracting

Owners commented that contractors benefit most from DBB PDS in that the selection process is very objective and the opportunity for profits especially through

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[70] ORS 351.086 Oregon University System exempt from certain laws; authority to contract with public agencies. (1) Except as otherwise provided in this chapter and ORS chapter 352, the provisions of ORS chapters 240, **279**, 282 and 292 do not apply to the Oregon University System.

"change orders" (one commented "Lots of"), is higher, including through deceptive bidding practices.

Design professionals gain little benefit from DBB, according to owners, except that it is a common practice that designers are familiar with and that they have complete control over the design process, and once they've finished the design, "they are done."

Owners benefit from the bid process by obtaining the lowest first price and, depending on the quality of the contract documents, perhaps the lowest overall price – after claims and change orders. Owners may even "get a bid price below what the actual cost is."

5.5.2.4 Owner's Perceived Drawbacks of DBB Contracting

Owner's comments on drawbacks of DBB were principally concerned with money issues and risk, principally that the contractor has higher risk and initial profit margins are low with the "opportunity to lose a lot of money." Design professionals have to do a better job of writing specifications and drawing the plans to avoid claims by the contractor, and they may have to redesign certain parts of the job to meet the budget and are forced to work in an "adversarial situation at times." Owners face the prospect of getting a contractor they do not know or may not want, and may be faced with a lot of change orders, which drive up the cost of the work beyond the allowable budget. The public in general may suffer from higher cost, lower quality work, particularly if the "contractor embraces claims as a way of doing business."

5.5.3 Design Professionals

Design professionals accounted for about 18% of the total comments and were fairly balanced in assessing benefits (45) and drawbacks (43) but gave the majority (60%) of their comments on the CM/GC PDS.

5.5.3.1 Design Professional's Perceived Benefits of CM/GC

Design professionals comments regarding benefits accruing to the contractor from CM/GC were generally along the same lines as the contractor saw them: "less adversarial relationship;" "less risk from unknowns;" the ability to have "input on constructability issues." Oddly, design professionals commented that the administrative costs for the contractor and cost of preparing for the selection cost less, when in fact administrative costs are necessarily higher due to pre-construction services and additional cost reporting required for a cost reimbursable contract. Also, the cost to prepare the kinds of documents required for a CM/GC selection are significantly more detailed and difficult to prepare than a simple bid, particularly when the total cost of marketing is factored in.

They themselves benefit from the process by working with the contractor in a less adversarial context during the design phase, resulting in fewer instances of "redesign" for budget purposes.

Owners and the public in general benefit from "less risk of change orders;" "more certainty of the final costs;" lower "possibility of claims;" and getting "higher quality" projects that have a better chance of being completed "on time." These perceptions are not entirely borne out in this research; while quality may be higher, and that is difficult to judge, the CM/GC projects do not have a higher likelihood of finishing on time or lower total change order costs.

5.5.3.2 Design Professional's Perceived Drawbacks of CM/GC

Design professionals probably see themselves as the most negatively affected by the CM/GC PDS as evidenced by the following comments:

- Must be willing to spend some extra time revising documents when input is gathered from contractor during pre-construction.
- Contractor can control the pre-con phase, extended time for architect during design.
- Possible conflicts when more individuals are involved in the design.
- Higher price, typically about 15%.
- With no competition, it is a more difficult position if it is felt that the price of a system should be less.
- Required extra time for inclusion and involvement with the contractor, typically the contractor is not very good at estimating design drawings instead of completed documents and specifications.

Contractors, on the other hand, suffer only from the fact that the original estimates and budgets may not reflect the final product, particularly when the contractor has to "lock-in" a price based on incomplete information. The owner and public in general may suffer from higher costs and unscrupulous contractor pricing and the possibility that a contractor may be selected for factors other than being the best to do the job based on "relationships and not qualifications."

5.5.3.3 Design Professional's Perceived Benefits of DBB Contracting

The basic fairness of the bidding environment is the major benefit of DBB PDS for contractors according to the design professionals, but they see little benefit accruing to themselves (only four comments, and none dealing with the actual "work"). Again, design professionals comment that owners and the public in general benefit due to lower initial costs (and possibly lower total costs) and having a larger pool of contractors looking at the job.

5.5.3.4 Design Professional's Perceived Drawbacks of DBB Contracting

The drawbacks to DBB PDS come from increased risk due to unknown pricing prior to bid, which may cause the project to be dropped or redesigned. They note an increased risk of claims, a more adversarial relationship that can generate "conflicts and claims [that] could delay completion." Finally, design professionals note that the "most qualified contractor is not always selected," which may mean a lower quality project.

5.5.4 Attorneys

The unique perspective of the attorneys in this survey is described above. As a group they contributed sixty one (61) of the nearly five hundred comments, or a little more than 12% of the total responses. One thing that sets the attorneys apart from some of the other respondents is the length of some of their responses, many being several lines long.

5.5.4.1 Attorney's Perceived Benefits of CM/GC

Seifer notes that, "any contract serves the primary purpose of allocating the risks and responsibilities between the parties" [185], and therefore it is not surprising that the attorneys focused many of their comments on "risk" and risk reduction. With respect to the benefits that accrue to the contractor:

- The contractor is clearly able to identify its risks and negotiate specific terms in the contract that it would otherwise simply have to accept as part of the RFP or ITB process, which may increase its profit and decrease its risk on the project. It may also exclude out of the project, elements it does not want to undertake, that it would otherwise have to accept.

- Less risk more certainty to profit percentage, may be low but fair certainty that that's what you book.

- I think for the contractor the negotiated public contracting process offers much more "certainty". The negotiated process involves more opportunity to understand the project and the owner's objectives and a contractor is much surer of the costs, adequacy of design plans and overall reasonableness of the construction project before it begins. The negotiated process involves the contractor at a much earlier state, which benefits project communications which can lead to more certainty.

Attorneys also commented on the flexibility granted the contractor and the owner under CM/GC, and the better team relationship that seems to result:

- OAR's do allow some ability to negotiate some terms of the contract - time of performance - LD's, can't negotiate statutory requirements i.e. prevailing wages.

- Fee based performance - advantageous because becomes more of a "Partnered" less adversarial.

Design professionals, according to attorneys, benefit least of the stakeholders; in fact, only one genuinely positive comment was made:

- I think the project design professionals benefit from a negotiated project for the same reasons the contractors and owners benefit--more certainty. The contractor and designers talk much earlier in the process, and this helps to define issues and affords everyone an opportunity to become familiar with the project objectives. The standard bid process has the designers estimating construction costs in a vacuum, which leaves the public owner in a tough position in terms of project budgeting. When a project is put to bid and it comes back too high, this leaves the owner frustrated and the designers looking bad. The negotiated process helps to reduce the chance of error, lawsuits and disappointments.

Attorneys commented that owners and the public in general also benefit from both the reduction in risk (which includes greater cost and schedule performance certainty, as well as a lower chance of claims) and the different contractual structure:

- Greater certainty as to completion: in a Lump sum the owner chooses the time, in CG/MC the CM negotiates the date to complete and that means the date is more certain. In LS the GC might just add LD's to bid price risk.

- I think the project owner benefits by being more assured that he/she will get what he/she expects. In my opinion and experience, the ordinary/regular "low bid" process was a lot like a game of chance--you really didn't know what you were getting with that low bid. Furthermore, it's tough to throw out the low bidder unless it is obvious way, way, way, way out of any reasonable ball park. Low bidder doesn't necessarily mean highest quality either. However, high bidder doesn't mean high quality either. That's my point: price shouldn't drive a public (private or any other kind) of project! With a negotiated public contracting process, the public owner gets to introduce many more issues (i.e. quality, timeliness, project coordination, involvement of MBE/WBE & DBE's, etc.) into the discussion. Being able to introduce those types of substantive issues into the discussion with a contractor is a good thing for the public.

- General reduction of claims, less pass through claims.

- Single point of responsibility: owner does not get caught between a designer and the contractor.

Perhaps because the owner can select the CM/GC contractor on a basis other than lowest price, overall project quality is seen as another benefit of the CM/GC PDS:

- Prescreen and solicit good capable contractors, not just everybody that is not irresponsible.

- Price can become a secondary selection criteria, could be quality.

- I believe the public at large benefits from higher quality projects that are built more on time and within budget. The reason is that the (astute) public owner can build a multitude of incentives into a negotiated deal to ensure that the contractor is highly motivated to do a great job. For example: a negotiated deal might include performance incentives (i.e. sharing in a projects savings), which can help boost a contractor's margin. Those kinds of "money in the pocket' incentives work, and the public at large benefits. Theoretically, the public benefits from lower taxes, but more directly the public benefits from better projects.

5.5.4.2 Attorney's Perceived Drawbacks of CM/GC

While attorneys as a group recognize several benefits to the use of CM/GC on public building projects, their observations also caution significant drawbacks for all of the stakeholders. In the case of "contractors" these are financial market-related risks:

- Fewer contractors have the ability to participate.

- Less than level playing field to get the benefits of public works.

- Tends to favor larger, union-oriented contractors (my observation) at expense of smaller shops.

- If an owner doesn't use adequate safeguards, the negotiated public process can easily turn into a "closed" process. This type of process can reduce competition because usually the process starts with an RFI to narrow the field to the relatively small group of contractors who will be asked to submit answers to an RFP. The contractor who wins the RFP is the one who gets to negotiate. This can be a closed process that hurts contractors, particularly smaller, less RFI/RFP savvy players.

And particularly with respect to subcontractors:

- Second tier subcontractor - it is a beauty contest against/between big contractors. Locks out smaller contractors, nobody gets fired for buying IBM syndrome. This leads to some economic waste because the lack of competition in the long run will eventually raise costs. Also, not every sub will bid the beauty queen and thus the public will not get the lowest price possible.

This comment is practically the only comment received that specifically recognizes the fact that by reducing the competition from several general contractors competing for a project to one negotiating for the work, that other parties could be damaged. Further, here the respondent points out that, "in the long run [this process] will eventually raise costs," which is precisely what theory would predict and a reasonable interpretation of what the state found in [135]. However, recall from Section 2.6.3, the court in ABC v. Tri-Met expressed little concern for subcontractors and the relationship between subcontractors and the general contractor, opting instead to interpret ORS Chapter 279 to principally apply to the relationship between the government agency and the general contractor.

Attorneys did not consider the design professionals to suffer many drawbacks from the CM/GC PDS. In fact, the sole comment on this subject from attorneys concerned reduction in fees due to fewer field adjustments, which in some sense is not necessarily a drawback, particularly if the designer is on a fixed-fee basis.

Owners and the public in general lose out some when competition is reduced and in fact commented that CM/GC can make a problem project worse for owners:

- Often no cost savings.
- Less competition may not lead to best or most effective results; CM/GC is best when used with some competitive selection process.
- Often cost savings very elusive.
- When it works, it works well; when it fails, it results in major disasters (i.e. owner has less control over outcome, particularly during course of performance).

In addition, attorneys recognized there may be some unforeseen costs associated with implementing the process that the owner may not consider:

- I think the primary drawback for the project owner is the costs and personnel time it takes to effectively conduct a negotiated public contracting project process. This type of construction delivery system is not for every public owner. The public owner must devote the appropriate level of time and have the necessary staff of consultant talent available to "negotiate" a good/fair contract.
- The negotiated process, if not handled properly (see comments above) could actually lead to higher project costs without commensurate benefits. Also, as I mentioned earlier, the negotiated process allows a public owner to more creatively and legally address other relevant issues such as MBE/WBE/DBE involvement, but unless the public owner has skilled, experienced staff doing the negotiating, then such goals may not be attainable.

5.5.4.3 Attorney's Perceived Benefits of DBB Contracting

The benefits of DBB PDS, according to attorney respondents, are few and limited to issues like objectivity and fairness in contractor selection. For contractors, they also observed that DBB can result in more profits if executed properly. Owners may be able to shift more risk to the contractor, if, of course, the plans and specifications are adequate.

And, once the bid price is received, there may be greater certainty as to the final cost, although that observation was disputed by the other parties in the survey above.

5.5.4.4 Attorney's Perceived Drawbacks of DBB Contracting

Attorneys made the fewest comments regarding drawbacks to DBB, with only ten (10) comments, and one of those being "few." The two principal comments appear to be that the owner does not realize the benefit of an experienced and creative building professional during the design that may result in delays and additional costs. In addition, as one respondent observed:

- Nothing is "guaranteed" in the construction work, and a project that begins as a lump sum bid might end up with a stretched budget in the end. Things happen along the way and the "lump sum" may have to change, and the owner has to be financially prepared for that potential reality.

And design professionals may be among those carrying the greatest burden under this PDS as one comment suggests:

- I think the design professionals are under a lot of pressure to do things right (well documented design, excellent cost estimates, etc.) with a lump sum bid job. The owner will really be very dependent on the accuracy of designer documents and very upset if things go awry with what he/she thought was a "lump sum" bid.

5.6 Summary of Survey Responses

One constant theme throughout these survey responses is the belief that the CM/GC PDS process reduces risk by giving the builder a better understanding of the plans and specifications at the time when the price for the work is established. Since the process includes the builder during the design phase as an equal member of the construction team, the relationship between the owner, contractor and architect/engineer is greatly improved. The builder's input during design and estimating throughout the design process is felt to avoid the need for costly redesigns and change orders after the contract price is established, thus making for greater certainty of the project costs to the owner. Also, since the CM/GC Contractor is on the team during the early stages, it is felt that a more reasonable and accurate construction schedule can be developed, leading to greater certainty in the completion of the work. The better relationship between the parties is thought to deliver a better project, higher quality, on time and perhaps at a lower cost. There is near uniform agreement that there are fewer "claims" for additional compensation and change orders when CM/GC is used, although the data from Oregon shows that "claims" are actually rare in both CM/GC and DBB projects. By no means are CM/GC projects immune from "claims" as documented in Appendix F above. Nevertheless, the word "claim"[71] (or lack thereof) is consistently used to describe one of the benefits of CM/GC and the drawbacks of DBB.

The assertion that CM/GC results in lower and more predictable costs is contrary to what competitive bidding theory and empirical studies would suggest. The data from the Oregon projects in this research does not support the conclusion that there is greater predictability in either cost or schedule metrics, which is consistent with the CII study

[71] The term "claim" evokes an almost irrational emotional response from both owners and design professionals, as though all "claims" are frivolous and without merit. Yet, a large portion of claims are settled in negotiation or mediation or entitlement is established and quantum awarded by a court. Owners, almost uniformly fear what they describe as "claims oriented" contractors, who in the owner's mind underbid the costs of a job in order to make it up on change orders and claims. This, in spite of the fact that these contractors on average appear to save the owner money, according to [135].

[183]. The research performed by Lattimer [135] suggests that having multiple bidders on a project creates significant cost savings on the overall project; however, these results are disputed by the building Contractors. They assert that CM/GC results in lower costs, particularly on complex building projects, which are significantly different from the highway contracts studied in [135]. Attorneys, some owners and design professionals do agree that there may be higher overall project costs, owing in part to the fact that there is an extensive pre-construction effort and a higher level of cost reporting required in CM/GC, both of which are costs not found in DBB. However, they point out, as do the contractors, that the fees contractors extract in CM/GC are lower on average because they reflect a lower risk than DBB contract. Also, the fact that the owner pays more for pre-construction work actually results in higher quality projects, with lower risk of redesign and change order costs. Left unsaid, of course, is the fact that the initial negotiated GMP has a higher likelihood of including the possible change order costs up front, rather than on the back side of the project. In short, since the CM/GC contractor has an opportunity to clear up any misunderstandings or ambiguities in the plans and specifications prior to establishing the GMP, it is less likely that he will wrongly interpret an ambiguity in the contract documents that results in a lower initial cost.

Risk to the contractor in DBB is cited as a major drawback to the DBB PDS, in spite of the fact that Kagel and Levin [118] determined that construction contractors rarely suffered winner's curse and that bonding of major subcontractors can ameliorate some of the single largest risk to the general contractor in DBB. But there should be no doubt that construction contracting is a risky business and contractors have been known to make a lot of money on projects and lose a lot of money on projects. The CM/GC PDS through negotiated procurement clearly reduces the risk of those kinds of profit and loss swings.

The adversarial relationship created under DBB PDS is another major issue discussed as a drawback to DBB and conversely, its reduction as a benefit of CM/GC PDS. The reason for this paradigm is probably multi-factorial, but most likely is rooted in the cross-financial objectives of the parties as pointed out by one of the respondents: The "contractor's objective is to make money while the owner's objective is to cut costs," and that naturally leads to friction. One construction company owner interviewed in the course of this research stated that in the 1960's his company was turning away work with fees of twenty to twenty five percent (20% - 25%). Today, large DBB projects are bid in the range of three to four percent (3% - 4%) and CM/GC jobs result in negotiated fees as low as two percent (2%)! That reduction in fee consequently reduces the contractor's ability to absorb additional costs for unforeseen conditions or errors in the plans and specifications. That means those costs must be passed on to the owner, who arguably gets the benefit of the lower initial cost.

6 Case Comparison Review

The principal reason that construction projects are offered by bid in an auction market institution as opposed to other pricing models is that they are generally considered unique. This characteristic also makes it very difficult to compare project outcomes. Critics of such analyses have rightly pointed out that you will never build the same project in the same location under the same environmental, financial and market conditions a second time [150]. As much as analysts try to measure one project against another, the reality of the construction environment and differences between projects make comparisons between all but the simplest of structures subject to doubt. For that reason studies like [75] and the present one tend to measure project performance in terms of metrics like cost and schedule growth instead of cost efficiency measures like cost per square foot. The present research, as well as the studies by the CII cited in Chapter 2 and Appendix E, have evaluated PDS's, in short by their ability to assist construction project management in delivering projects as promised at the time the deal was established.

6.1 Research Question #5: Direct Project Comparisons

A senior partner in one of the firms that supplied data for this research pointed out that the Oregon database includes three elementary schools that were constructed using essentially the same design. Two of the school designs were based on the first and were constructed in the same time frame, using different PDS's. He suggested that a case study could be performed on those schools and went on to point out that his firm, which designed all three schools for the same Owner, had different experiences with the different PDS's used.

6.1.1 Nancy Ryles Elementary – Prototype School

The Nancy Ryles Elementary School located in the southern part of the Beaverton School District was built in 1991 as a prototype school design for the rapidly growing District[72]. The elementary school was originally approximately 56,000 SF and was built using the CM/GC PDS. The original GMP was $4,675,000 and incurred cost and program growth to a final $5,041,777 actually paid to the CM/GC, an increase of 7.85%. The school was opened on schedule and incurred no schedule growth. In 1996 Nancy Ryles underwent a second phase that added several additional classrooms and approximately 12,000 to 13,000 SF, for a new total of 68,000 to 69,000 SF. The second phase was a DBB project.

The fact that the project was a prototype may have more to do with the fact that the cost growth was slightly higher than the average for projects in the Oregon database for both CM/GC and DBB PDS's than the choice of PDS itself. Schedule growth at 0% was lower than the mean of the Oregon database for both PDS's[73].

Once completed, and the design consultants and owner management team had compiled all of the "lessons learned" from the job, the Nancy Ryles school was to serve as

[72] Information on the Beaverton School District can be found at www.beaverton.k12.or.us
[73] It should be noted that very few of the schools in the Oregon database show that they finished early and nearly all of the schools finished on time. This is in part due to the unique structure of the "school year" in Oregon and elsewhere, that the school building site is essentially vacant during the summer months and there is little value in completing school building in July when it won't be occupied until September. Conversely, it is extremely important that the building be ready for occupancy when the school year begins or there will be serious educational, social and financial consequences to the District and the student body.

a prototype for future similar sized elementary schools in the district. The designs for future schools in the district over the next decade or so would use essentially the same "cookie cutter" type design layout, modified and oriented to fit the specific sites.

6.1.2 Bond Levy Construction

In the November 1996 general election, the Beaverton School District successfully passed a capital construction levy in order to fund the construction of new schools needed to accommodate the rapidly expanding student population in the district. There was an immediate need for a new elementary school in the north part of the district, with a new elementary school in the southern part of the district needed a year later, in the fall of 1999. After some time to digest the outcome of the election, to refine their student population estimates, identify sites, and decide on construction priorities, the District directed their Architect to "dust off" the Nancy Ryles prototype drawings and update them for the new site selected along Northwest Saltzman Road. The school needed to be open for the 1998 school year, only eighteen (18) months more or less from the beginning of design.

Most elementary school construction programs, particularly under DBB, are a twenty four (24) to thirty (30) month process. This school, to be named Findley Elementary after the family that had farmed the area for five (5) generations, had to be opened in a year and a half. This being the case, the Local Contract Review Board[74] declared an emergency and exempted the new school project from the competitive bidding

[74] See ORS 279.011(1) and ORS 279.055 for definitions and duties of the Local Contract Review Boards.

requirement under ORS 279.015, allowing the District to immediately bring on a CM/GC to accelerate or "fast-track" the construction process.

The District immediately solicited for competitive proposals from the construction community to perform CM/GC services on the project. The process involved a pre-qualification and selection phases that included submitting a proposal with the highest rated CM/GC proposers to be interviewed. When this "RFP" process was complete, the District selected and entered into an agreement with the highest rated CM/GC proposer.

The construction team, consisting of the District management, the architect's team, and the CM/GC, immediately started to work on plans and budget. A target amount had been set by the District and the architect, based in part on the Nancy Ryles project costs with scope additions and site work changes for the new school in order to meet the overall bonded program requirements. The District determined that the new school would be larger than Nancy Ryles, approximately 70,000 SF. Therefore, the architect's team began by making changes in the plans based on scope changes and the site work, while the CM/GC started to put together construction budgets for the eventual GMP. The District team had the responsibility of deciding what to add and what to take out, depending on the costs and the funds available.

The process did not go smoothly. The CM/GC's cost estimates were significantly over the budgets the District and their architect had established. The architect made numerous revisions to the plans, at the direction of the District, in order to reduce the overall project costs. According to the design team, this was a very frustrating period because, "the CM/GC would not come to the table with solutions or suggestions for cost savings; they merely gave us a cost estimate for the design solutions [the architect's team] developed" [215]. In the end, the original CM/GC was not able to negotiate a GMP with the District and the decision was made to part ways.

Months had elapsed since the original RFP had gone out and the time frame for construction had necessarily been reduced, making the situation all the more serious for the District. Luckily, the District was able to come to a quick agreement with the second highest rated CM/GC to take over the project, and according to the architect, "within two to three weeks, they had negotiated a GMP" that was substantially lower than the previous CM/GC had proposed and was within the District's original target range. The original GMP for the project was $6,905,000. The project proceeded as required to be ready for the opening of school in the first week of September 1997; however, the project did experience cost growth of approximately seven percent (7.0%) over the original GMP to a final amount paid of $7,388,000 (or an additional $483,000.)[75]

At the same time the Findley School was initiated, the District identified the need for another elementary school in the south. However, that school, which would come to be known as the Scholls-Heights Elementary School, would not be needed until the start of school in the fall of 1999. This meant that there would be no need to "fast track" the job, as it fell within the normal program parameters of DBB for schools, particularly since the near identical design was being implemented at Findley. The decision was made to use DBB for the Scholls-Heights School, whose name was taken from the Oregon Pioneer and great-nephew of the woodsman Daniel Boone, Peter Scholls.

[75] The Nancy Ryles School had cost growth of 7.85% for a total of $366,777.

Scholls-Heights was bid while the Findley School was under construction, and while the two schools had nearly identical floor plans, there was some difference in the amount of site work (less at Scholls than Findley). Scholls is listed in the Oregon database as being slightly smaller at 69,000 SF compared with Findley at 70,000 SF, but according to the Architect, they are the same design. Scholls-Heights received an unknown number of competitive sealed bids[76] and awarded the job to the low bid contractor for a price of $6,405,000, exactly $500,000 less than the Findley GMP established just a year earlier.

The architect commented that while some of the difference could be attributed to the site work differences, "There was no one big difference in the projects that accounts for the difference in costs." "The Scholls project was consistently lower in every cost category." Furthermore, in spite of the fact that inflation during the period was very low, there was some cost inflation, and more importantly, the employment levels in construction during the Scholls project were at record levels in Oregon, higher than during the Findley project[77]. With higher levels of employment, fewer bidders feel the need to be risk taking, thus you expect higher not lower bidding. None of the environmental or endogenous factors accounts for the difference in costs except perhaps the fact that one project was competitively bid and the other was not.

Scholls-Heights opened on September 7th, 1999; as with Findley, the project was on time, but did experience cost growth. However, perhaps due in part to lessons learned

[76] The architect had no records of this type for the project, having turned them over to the District, and the Beaverton School District was unable to locate any files related to bidding of the job for the purposes of this research – meaning that they may still have the documents stored somewhere but there was nobody available to look for them and the only way they could be found and retrieved would be if someone paid the District to do so.

[77] The Oregon Economic Forecast showed that 86,500 were employed in the construction sector in the third quarter of 1999, whereas one 83,300 were employed in the third quarter of 1998.

on Findley, the cost growth on Scholls-Heights was considerably less, at only three percent (3%) for a total of $192,150. In the final analysis, Findley cost the District nearly twelve percent (12%) more than Scholls-Heights, nearly $10.00 per square foot of building floor area, which according to the architect, could not be accounted for by any specific difference in the jobs [215].

6.2 Summary of the Case Comparison Study

Table 26 presents a summary of the two projects evaluated in this chapter.

School:	Findley	Scholls
PDS:	CM/GC	DBB
Year opened:	1998	1999
Size (sf):	70,000 sf	69,000 sf
Original GMP/Bid:	$6,905,000	$6,405,000
Final Amt. Paid:	$7,388,000	$6,597,150
Cost Growth:	$483,000	$192,150
Cost/sf:	$105.54	$95.61
Schedule Performance:	On time ~17 Mo.	On time 24 Mo.

Table 26 Summary of Case Comparison

As much as anything, this case comparison study demonstrates the difficulty of comparing two construction projects, even two that have the same design, same design team, same owner and similar time frames. How much were the costs in Findley affected by the shortened time frame is really anybody's guess. It is known that the CM/GC on the Findley job brought to the owner the three supposed lowest subcontract bids for each type of work, and unless there was some convincing reason not to, the low subcontractor was selected. But what is not known and quite possible is that given the shortened time frame, the CM/GC and Owner may have selected subcontractors that could perform the work in the time allowed as opposed to the cheapest. In addition, as seen in the legal cases described in Section 2.6.3, CM/GC's have broad discretion over whom they wish to "pre-qualify" for bidding subcontract work. The CM/GC on the Findley project may very well have not solicited or accepted bids from weaker but cheaper performers[78].

The analysis in Chapter 4 showed that, based on the overall construction management model, CM/GC projects perform better than DBB jobs. However, recall that the statistical analysis of the output metrics indicated that there was no statistically significant difference between the outcomes. It should be pointed out that both Findley and Scholls-Heights fall within the cost control metric means for the overall study and both projects performed well in schedule performance (both with 0% schedule growth). What the case study indicates perhaps is that while broad statements can be made, there is no way to precisely predict the outcome of a specific project. And the choice of the PDS needs to be carefully evaluated to meet the specific needs of the project and promises no guaranteed outcome.

There may be another factor to be considered regarding the use of CM/GC on certain types of projects. In two extended interviews with the architect and his partners and staff for this research (the latter being [215]), these design professionals questioned the value added by the CM/GC in public school projects. In short, the professionals

[78] The CM/GC project team was not available for comment.

commented that they had designed literally hundreds of schools in Oregon and Washington in their three decades of being in business, as one commented, "What is the CM/GC going to bring to the table that we already don't know or haven't seen before?" He added, "We've seen a lot more schools than any single contractor has because schools are pretty much all we do, and furthermore, they are not incredibly complex jobs like a hospital or require cutting edge materials or technology like a new office building."

While the Architect's comments and opinions here must be given a lot of credibility, the analysis in Section 4.3.1 indicates that CM/GC school projects performed as well or better than DBB school jobs. There was fewer than half the number of CM/GC schools than DBB schools, but more CM/GC schools, seven, achieved efficient or near efficient DEA scores, compared with only five of the DBB schools. But these analyses do not account for differences felt by the design consulting team, which may be substantial. As one of the interviewee's noted, the architect is usually the one that ends up bearing the cost of changes incurred during the CM/GC process. By example the architects discussed a school designed for a rural Oregon district. The CM/GC maintained that they would be unable to get qualified carpenters for the job, so therefore it should be a steel frame building. The architect objected but was directed by the owner to make it a steel frame. When the pricing started to show that steel would not be competitive with wood, as the architect predicted, the architect was directed to redesign the structure using wood. This meant a change to all of the details and a redesign of the main structure. Since the "team," including the owner, architect and CM/GC, had agreed to "bring this job in on budget" the architect received no additional compensation for redrawing the plans and rewriting the specifications for the change in structure.

This case comparison shows that CM/GC projects do not always result in a "substantial cost savings" to the public contracting agency, nor that CM/GC projects will always result in substantially lower construction cost growth than similar DBB projects. However, the case comparison also shows that CM/GC can deliver jobs in a shorter overall time frame (including both design and construction) than DBB.

7 Summary, Conclusions and Additional Work

7.1 Summary and Findings of Analysis

This research evaluates the public policy in Oregon that allows public agencies to exempt projects from competitive public bidding and negotiate with a construction contractor (selected in a competitive, but subjective process) to build a project. The analyses presented in this dissertation shows the public policy requirement, that the pubic agency show that the exemption from competitive bidding will result in substantial cost savings, is not supported by the data analysis.

This research concludes that the exempted projects, the CM/GC projects, are more efficient than the competitive bid, DBB jobs, only when the entire input-output model is considered. CM/GC projects do not outperform DBB projects in terms of cost and schedule control metrics alone. Empirical analysis, including the case study project comparison, shows that the CM/GC projects may be more costly than similar DBB jobs. This is also confirmed by the opinions of various stakeholders surveyed.

CM/GC projects become more efficient than DBB projects through the ability to fast-track the work. That is, to start the actual construction work with less information in terms of the completeness of the plans and specifications. Since fast-tracking appears to be the principal benefit of CM/GC, it should be the principal reason projects are exempted.

Project stakeholders are consistently incorrect in their assertions that the use of CM/GC PDS reduces overall project "risk," since there is no statistically significant difference between the DBB and CM/GC jobs with respect to cost and schedule control. These findings from the Oregon database were validated by similar data from other studies, principally [51, 75, 99, 126], in spite of the fact that Konchar and Sanvido [75, 126] reached alternate conclusions.

7.2 Recommendations

We recommend that the State of Oregon revise the current public policy and shift the exemption requirement from "significant cost savings" to a focus on "schedule" requirements, specifically the need to fast-track the project. Also, including an analysis of other factors, such as project complexity as suggested by the Oregon Public Contracting Coalition [56], should be considered.

Second, we recommend that the state do a better job enforcing the requirements of ORS 279.103, both in terms of getting the reports done, and also making certain that the reports are in fact the "objective analysis" required by the statute. It may require the state to shift the responsibility for collecting and reviewing these reports from the Department of Administrative Services to the Secretary of State's Audit Division.

7.3 Future Work

This research is neither the final word on this DEA application or the public policy debate regarding the procurement of construction services for public building projects. Clearly there is a need to better understand the process by which certain types of information are converted into *inputs* for DEA models in order to apply DEA to this broader set of service sector applications. The process construction contractors undergo is similar to the process that any professional consultant undergoes in order to produce a product or outcome for an owner. Whether that person is an accountant, architect or engineer, all are given a varying amount of data from their client, which they convert into useful *inputs* through some "process model" and eventually into *outputs*. The next step in this process is to investigate, both in theory and application, different transformations of the data to better understand and model "information" as used as an *input* in the DEA model.

As for the policy debate regarding construction contracting project delivery methods, it is clear from our research that the Oregon legislature must to come to grips with the fact that the current policy is simply unworkable since it cannot be supported by either empirical or theoretical data analysis. The focus of this effort should be in better aligning the policy goals with the benefits that can be achieved by the different methods. The fact that the public pays no additional cost for starting a project at the conceptual or preliminary design phases is a clear indication of the advantages presented by the method that is ignored in the policy statement.

7.4 Limitations of the Study

The limitations of this study were addressed in Chapter 1 and are repeated here in brief:

- The study is limited to building projects and may not be generalized to the broader construction industry that includes heavy highway and industrial projects.
- The study considered only building projects in Oregon and may not be generalized to all states (although Washington state is discussed) or the federal government.

- The Expert Panel members may have been biased, but the panel was balanced with members from three stakeholder groups. Furthermore, the metrics derived from the Expert Panel were substantially similar to those used in the other PDS studies, and much of the data obtained from the Panel members was corroborated from other sources.
- The projects studied are not a random sample of the population of all projects, but the study contained the majority of CM/GC projects identified in the database (111 of 136) and over half the DBB projects (104 of 193) constructed in the state over the study period that fit the criteria for the study (note that 68 projects were identified and that the PDS was unknown, although at least two of these were DB and the majority of the others were probably DBB.)

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Appendix A: Glossary of Terms

% Complete @ Bid or GMP	An estimate or opinion based on the project team's experience. As a general rule, Conceptual drawings are considered 10 to 50% complete, Schematic design can range from 40% to 75% complete, Preliminary design range from 60% to 90% complete, and Working drawings, somewhere between 90% and 100% complete. Experience tells us that 100% complete drawings are extremely rare in large complex construction projects of the type considered in this study.
AP – Architect's Proposal or Proposal Request (PR)	An Architect's Proposal or Proposal Request is similar to an RFI generated by the owner or his architect. Unlike an RFI, the AP presupposes that the change or addition will affect the cost and schedule of the project. AR's like RFI's are followed by a COR and finally a CO.
Bid	By Bid, Bid Price or Bid Fee, we mean the competitively bid total price, or in the case of Bid Fee, the Contractor's fee at the time of the competitive bid – prior to buy-out or any augmentation.
Budget Control	The Budget Control metric is calculated as the: (Original Budget, Bid or GMP)/(Actual amount paid, to the contractor or total final billings at the end of the job.)
C.O. – Change Order	A Change Order is an amendment to a contract.
CII	Construction Industry Institute at the University of Texas, Austin (http://construction-institute.org/index.cfm) performs research on the construction industry including benchmarking or project performance.
CM/GC	CM/GC stands for Construction Manager/General Contractor. This method of contracting results from a negotiated procurement. The term CM/GC is also used to denote the entity performing the work such as: "the CM/GC on the project."

Contractor	The term "Contractor" is generally used to denote the entity that oversees the construction project, it can be used when referring to either a DBB construction contract or a CM/GC construction contract, but generally when the term "contractor" is used it implies a DBB project.
COR – Change Order Request	A Change Order usually begins with a Change Order Request by the contractor and most CO's contain a number of COR's packaged together in one contract amendment.
DB	Design-Build is a method of contracting (a PDS) that is used in the private sector and is gaining use in the public sector, however DB is not directly evaluated in this study.
DBB	Design-Bid-Build is the traditional form or method of contracting that involves an owner hiring an architect to design a project, then letting the work out by competitive bidding among a group of qualified contractors.
DCVR	Design Clarification Verification Request is another term used synonymously with RFI by different firms. DCVR is not used in the text of this research simply by choice of the author.
DEA	Data Envelopment Analysis is the methodology used in this study. See Tab 8 for explanation and detail.
DMU – Decision Making Unit	Decision Making Units are the fundamental entities used in the DEA model as the basis for comparison. In this research, projects are the DMUs.
Fast-track	Fast tracking is a process whereby a project starts construction before the final plans and specifications for the work is complete. This process is designed to allow the beginning of certain work, like earthwork, foundations and primary structure to start before issues like tile, carpet and paint color have been decided on.

GMP	Guaranteed Maximum Price: it is typical in a CM/GC project for the CM/GC or "Contractor" to give the Owner a Maximum Price or GMP prior to starting construction, or when they are in the early stages of construction.
LD – Liquidated Damages or LD's	Liquidated damages are a common method in the construction industry to allocate damages that result from the inexcusable late delivery of a project to the owner. These are typically per diem damages that have a reasonable relationship to the actual damages incurred by the owner for not having beneficial use of the building. The relationship must be reasonable so as not be a penalty, but also, actual damages must be precisely incalculable.
LSB Method	Lump Sum Bid Method is another term meaning the same thing as DBB.
Original Budget or Bid	If the project is a CM/GC, the original Guaranteed Maximum Price. If the project is a DBB job, it is the original bid amount, including the accepted alternates, if any.
PDS	Project Delivery System, the PDS is the method of contracting for construction work, it is literally the way in which the work or product is delivered.
Profit	Profit is defined in this study as the Contractor's Fee, this is all money not included in the direct work or jobsite overheads. The Profit or Fee, includes the portion of the payment made to the Contractor to pay for home office overhead.
Project Manager	This is defined as the person generally in charge of the project and responsible for the financial performance, the quality of the work, and meeting the Owner's schedule, safety, and other performance requirements. Other titles used in some companies may be: Superintendent, Operations Manager, Project Engineer, Project Executive.
Punch List Item	List of uncompleted or corrective items of work to be done to complete the contract. These lists are prepared by the architect after an inspection of the project at substantial completion

RFI's – Request for Information	An RFI is a Request for Information or Design Clarification from the Contractor to the Architect, Engineer or Owner. It also may include an Architect's Proposal Request, but generally only if the Proposal Request is to correct some error or omission on the plans made by the Architect or Engineer. Some Contractors and some Owners or Architects may not use RFI's, or they may be called something else, or they may simply be included in project correspondence. In your best judgment, how many requests for design clarification were made by the Contractor to the Architect, Engineer or Owner.
RFP – Request for Proposal	In most CM/GC projects, the prospective vendors are required to submit an RFP, which contains information about the firm and description of the proposed project team, past history, and possibly approach to the work. From these RFP's the owner will either make a selection or narrow the field to a smaller number of prospective vendors for personal interviews prior to selection.
Schedule Control	The Schedule Control metric is calculates as the: (Original project schedule or time allowed under the contract)/(Actual amount of time expended at substantial completion.)
Total Final Billings	This is the total amount of money paid by the Owner to the Contractor, including change orders, contract extensions, and so on.

Appendix B: Expert Panel Members

Name	Title	Group
Barton Eberwein	Vice President, Hoffman Construction	Contractors
Joseph F. Bolkovatz	Vice President, JE Dunn Construction	Contractors
Jeffery V. Espedal	President, Pacific Coast Construction	Contractors
Roger Peterson	President, Marion Construction	Contractors
Tom Gerding	President, T. Gerding Construction Co.	Contractors
Jack Kalinoski	Retired, AGC Staff Member, Lobbyist	Contractors
Donald B. Kane	Retired, VP Finance, Drake Construction	Contractors
Patrick O'Brien	Owner, OTKM Construction	Contractors
Roger A. Lenneberg	Counsel, Performance Contracting	Contractors
Philip Carter	Project Manager, Baugh Construction	Contractors
W. Lee Schroeder	Retired, VP, Andersen Construction	Contractors
Joseph A. Yazbeck	Attorney	Contractors
Alan Killian	Vice President Turner Construction	Contractors
Patrick L. LaCrosse	Retired, President, OMSI, Former Executive Director, Portland Development Commission	Owners
Mike Burton	Retired, Executive Director of METRO	Owners
Lloyd Anderson	Retired, Executive Director, Port of Portland, and Portland City Commissioner	Owners
John Lang	Retired, Director, BES, City of Portland	Owners
Robert "Bob" Balaski	Retired, Director of Capital Projects, Port of Portland	Owners
David Bunnell	Contracts Manager, OHSU	Owners
William Nealand	Consulting Project Manager	Owners
Luis Ornelas	Consulting Project Manager	Owners
Ron Jackson	Director of Operations, Portland Development Commission; now Attorney in Private Practice	Owners
Todd Ainsworth	Attorney, Oregon Department of Justice	Owners
John Storrs	Architect. dec.	Architects
Raymond Boucher	Managing Partner, BML Architects	Architects
George "Bing" Sheldon	Partner, SERA Architects	Architects
Dennis Cusack	Partner, SRG Partnership	Architects
Philip Beyl	Partner, GBD Architects	Architects
Kevin Johnson	Partner, BOOR/A Architects	Architects
Donald P. Reay	Emeritus Prof. Arch. UC Berkeley, dec.	Architects
George Crandall	FFA Architects, ret.	Architect
David Evans	Chairman, David Evans & Associates	Engineers
Robert Wright	President, Thomas- Wright Engineers	Engineers

In addition to the Experts, several other people, agencies and firms played key roles in supplying information on projects, providing stakeholder survey responses, and other support for this research these include the following:

Andersen Construction
Baugh Construction, Oregon
JE Dunn Construction
Hoffman Construction Company
Kirby Naglehout Construction
Lease Crutcher Lewis Construction
Ramsay-Gerding Construction Company
Slayden Construction
Swinerton Construction
Wildish Construction
Dull Olsen Weekes, AIA
BOORA Architects
Yost Grube Hall
SRG Partnership
Zimmer Gunsul Frasca Partnership
Soderstrom Architects
gLAs Architects
Malhum Architects
Barber Barrett Turner
Arbuckle Costic Architects
The Seattle Daily Journal of Commerce
The Portland Daily Journal of Commerce
Oregon Health & Science University
Oregon State University
Portland State University
Southern Oregon University
University of Oregon
Western Oregon University
Central Oregon Community College
Portland Community College
Clackamas Community College
Oregon Department of Administrative Services
Oregon Department of Corrections
Oregon Department of Justice
Oregon Military Department
Oregon State Library
Oregon DAS Office of Economic Analysis
Oregon Secretary of State, Audit Division

Port of Portland
City of Portland
City of Salem
City of Beaverton
City of Gresham
City of Eugene
Multnomah County
Tillamook County
Washington County
Beaverton School District
Eugene Public School District
Portland Public School District
Gresham Barlow School District
Luis Ornelas
Franz Rad
Jerry Milsted
Robert O'Halloran
Arnold Gray
Martha Hodgkinson
Gary Christensen
Michael Bloom
Thomas Spaulding
David Douthwaite
John Weekes
Todd Anderson
Roger Brown
Sharon Peterson
Greg Peterson
Gary Wills
Glen Taylor
James Lyman
Karl Shulz
Mike Courchaine
Walt Lemon
Bruce Van Hine
Kathy Shears
Dirk Fraily

Appendix C: ORS Chapter 279.015

279.015 Competitive bidding; exceptions; exemptions. (1) Subject to the policies and provisions of ORS 279.005 and 279.007, all public contracts shall be based upon competitive bids or proposals except:

(a) Contracts made with other public agencies or the federal government.

(b) Contracts made with qualified nonprofit agencies providing employment opportunities for disabled individuals.

(c) A public contract exempt under subsection (2) of this section.

(d) A contract for products, services or supplies if the value of the contract is less than $5,000.

(e) Insurance and service contracts as provided for under ORS 414.115, 414.125, 414.135 and 414.145.

(f) Contracts for repair, maintenance, improvement or protection of property obtained by the Director of Veterans' Affairs under ORS 407.135 and 407.145 (1).

(g) Contracts between public agencies utilizing an existing solicitation or current requirement contract of one of the public agencies that is party to the contract for which:

(A) The original contract met the requirements of this chapter;

(B) The contract allows other public agency usage of the contract; and

(C) The original contracting public agency concurs.

(h) If a project is competitively bid and all responsive bids from responsible bidders exceed the public agency's cost estimate, the public agency, in accordance with rules adopted by the public agency, may negotiate with the lowest responsive, responsible bidder, prior to awarding the contract, in order to solicit value engineering and other options to attempt to bring the project within the agency's cost estimate. A negotiation with the lowest responsive, responsible bidder pursuant to this paragraph shall not result in the award of the contract to that bidder if the scope of the project is significantly changed from the original bid proposal. Notwithstanding any other provision of law, the records of a bidder used in contract negotiation pursuant to this paragraph are not subject to public inspection until after the negotiated contract has been awarded or the negotiation process has been terminated.

(2) Subject to subsection (6)(b) of this section, the Director of the Oregon Department of Administrative Services or a local contract review board may exempt certain public contracts or classes of public contracts from the competitive bidding requirements of subsection (1) of this section upon approval of the following findings submitted by the public contracting agency seeking the exemption:

(a) It is unlikely that such exemption will encourage favoritism in the awarding of public contracts or substantially diminish competition for public contracts; and

(b) The awarding of public contracts pursuant to the exemption will result in substantial cost savings to the public contracting agency. In making such finding, the director or board may consider the type, cost, amount of the contract, number of persons available to bid and such other factors as may be deemed appropriate.

(3)(a) Before final adoption of the findings required by subsection (2) of this section exempting a contract for a public improvement from the requirement of competitive bidding, a public agency shall hold a public hearing.

(b) Notification of the public hearing shall be published in at least one trade newspaper of general statewide circulation a minimum of 14 days prior to the hearing.

(c) The notice shall state that the public hearing is for the purpose of taking comments on the agency's draft findings for an exemption from the competitive bidding requirement. At the time of the notice, copies of the draft findings shall be made available to the public. At the option of the public agency, the notice may describe the process by which the findings are finally adopted and may indicate the opportunity for any further public comment.

(d) At the public hearing, the public agency shall offer an opportunity for any interested party to appear and present comment.

(e) If a public agency is required to act promptly due to circumstances beyond its control that do not constitute an emergency, notification of the public hearing can be published simultaneously with the agency's solicitation of contractors for the alternative public contracting method, as long as responses to the solicitation are due at least five days after the meeting and approval of the findings.

(4) A public contract also may be exempted from the requirements of subsection (1) of this section if:

(a) Emergency conditions require prompt execution of the contract;

(b) In case of sale of surplus property by a public agency, the number, value and nature of the items to be sold make it probable that the cost of conducting a sale by competitive bidding will be such that a liquidation sale will result in substantially greater net revenue to the public agency; or

(c)(A) The public contract is made between regularly organized fire departments, as defined in ORS 652.050, for fire protection equipment, as defined in ORS 476.005, and:

(i) The recipient regularly organized fire department makes a written request for the fire protection equipment to the transferor regularly organized fire department;

(ii) The fire protection equipment is surplus to or unusable by the transferor;

(iii) The total fair market value of fire protection equipment received by the recipient does not exceed $50,000 per calendar year; and

(iv) The transferor holds a public hearing, with notice given as outlined in subsection (3)(b) of this section, and finds that the public contract is in the public's interest.

(B) As used in subparagraph (A) of this paragraph, "public contract" includes a sale at no cost.

(5) The director or board shall adopt rules allowing the governing body of a public agency and the officer of a public agency for contracts under $50,000 to declare that an emergency exists and establishing procedures for determining when the conditions in subsection (4)(a) of this section are present. The rules shall prescribe that if an emergency is declared, any contract awarded under this subsection and subsection (4)(a) of this section must be awarded within 60 days following declaration of the emergency, unless the director or board grants an extension.

(6) In granting exemptions pursuant to subsection (2)(a) and (b) of this section, the director or board shall:

(a) Where appropriate, direct the use of alternate contracting and purchasing practices that take account of market realities and modern or innovative contracting and purchasing methods, which are also consistent with the public policy of encouraging competition.

(b) Require and approve or disapprove written findings by the public contracting agency that support the awarding of a particular public contract or a class of public contracts, without the competitive requirements of subsection (1) of this section. The findings must show that the exemption of a contract or class of contracts complies with the requirements of subsection (2)(a) and (b) of this section.

Appendix D: Example of Mark-up Calculation

In the discussion on winners curse and the broader discussion on competitive bidding in building construction contracts, the contractor's fee is studied as a principal strategic component of his bid. Many papers have been written regarding mark-up and contractor's fee; however few if any actually document how contractors derive their mark-up or fee in practice. The following discussion was provided by an Expert Panel Member and vice president of estimating for a large commercial building contractor.

While there is some amount of discretion in choosing the exact fee on any project, the contractor's choice is significantly constrained by business requirements and market conditions. The contractor is faced with two primary concerns in setting the minimum fee[79]:

1. Income necessary to run the company, and
2. Risk
3. What the market will allow.

The income necessary to run the company has two components required return on capital needed to acquire a bond and company overhead. The construction contractors, bidding on public projects, are highly regulated by the insurance industry. In order to bid on a public project, the contractor must (in nearly all cases) obtain a performance and payment bond also known as a "Miller Act" bond [20]. If a contractor is unable to obtain a bond, there is no reason to even consider bidding on a project.

The Insurer or Surety will require a contractor to post liquid assets or equity of between one tenth and one-twentieth the construction project volume. This is referred to as "Volume to Equity ratio." Meaning that, any contractor must have between fifty and one hundred thousand dollars in liquid assets in order to bid on a one million-dollar project. The exact amount of assets required by the surety will depend on the contractors' past performance and other factors. A relatively new contractor will be required to post a higher amount than a more established firm. The following is an example of how a contractor would calculate the return on equity (ROE) component of the fee:

Example 1

Assume: 20:1 volume/equity (i.e.: an established contractor)
Anticipating $2,000,000 in construction volume during the year
<u>$100,000</u> equity required

Determine the ROE required by the contractor, this depends on the investor, and other investments available such as stocks and bonds. Since there is a

[79] In this discussion of "fee" and through out this paper, fee incorporates all of the non-direct work costs required to run the company. These typically include main office overhead, salaries for executives and estimators as well as company profit.

lot of risk associated with an investment in a construction project, assume the contractor chooses 40% after tax ROE.

ROE is then calculated to be: $40,000 or roughly, $60,000 before tax.

The second component of the contractor's fee is overhead and can be calculated as in the following example:

Office Space:	$8,000
Office Equipment:	$5,000
Office Furniture:	$1,000
Estimators/Executives:	$60,000
Office Staff Salary:	<u>$26,000</u>
Total:	$100,000

Now, sum the two components:

ROE:	$60,000
Overhead:	<u>$100,000</u>
Total Fee Required:	$160,000
Average Mark-up of:	**$160,000/$2,000,000 = <u>8%</u>**[80]

This calculation sets one low limit for the fee. Another low limit, which is also influenced by the insurance industry is project risk. Project risk is evaluated in two ways, the contractor's direct labor risk and the overall job risk.

Labor risk is the uncertainty of labor productivity. Contractors estimate the cost of a given project by calculating the quantity of materials in place, and the amount of labor (and equipment) required to put the materials in place. From either the contractor's own historical records or industry pricing guides, such as Means [212], the contractor will draw an estimated labor productivity, expressed as either hours labor per unit of material or units of material per hour of labor. By applying the quantity of material to the labor productivity the contractor calculates the total number of hours, which in turn is converted to dollars by applying the appropriate wage rates. However, these estimates have uncertainty, which is reflected in the minimum mark-up. Typically, the labor uncertainty is on the order of 30%. In keeping with the example above, let us assume that half of the contractor's total volume is in labor. To calculate the minimum required labor risk fee:

---

[80] Thanks to Joseph F. Bolkovatz, Vice President of Estimating, JE Dunn Construction Company, Portland, Oregon, for providing this example.

Labor = $1,000,000
Labor risk = $1,000,000 x 30% = $300,000

Average Mark-up of: $300,000/$2,000,000 = 15%

Labor risk is a significant consideration for subcontractors, and a to a lesser degree general contractors. This is because general contractors typically self perform only a very minor amount of the labor on a given building project. More often, the general contractor has to assess the overall "job risk", that is the risk presented to the contractor by subcontracting 90 to 95% of the project to subcontractors. The assessment of this risk will vary from contractor to contractor and job to job and will depend on a number of factors as pointed out by Weitzman [217]. Again however, the insurance industry will set a minimum fee based on their analysis of the project risks, major subcontractors and so forth.81 This number will vary, however it is unlikely to ever be less than 2%. (This "fee required" figure is not the same as the actual "bond rate" quoted by the Surety. That rate will be substantially less for large contractors.)

Based on our analysis of ROE, costs and risks, we now have a set of three minimum mark-up's or fees to use: 8%, 15% and 2%. Since we are forced to cover all risks we must choose the largest of the minimum's, in this case, 15%.

These market and business constraints set the minimum mark-up or fee the contractor must bid, what is the maximum fee the contractor can bid? That depends solely on the current competitive market conditions, or "what the market will allow". Having set the minimum fee, setting the maximum or actual fee becomes a game where all of the bidders attempt to optimize their expected return based on probability of winning and amount of profit generated at a given fee (or bid).

[81] In fact, a Surety will not usually contact a contractor and prescribe a minimum fee, typically, the Surety's Agent will only get involved after a bid is won and review the contractor's bid at that time to determine if the fee is adequate, in order for them to issue a bond.

Appendix E: Prior Industry Studies

The Construction Industry Institute

The Construction Industry Institute is headquartered at the University of Texas at Austin and performs a substantial amount of research on construction industry, including benchmarking of construction project performance[82]. This research is supported by its members numbering well more than one hundred, including some of the largest public and private building organizations in the country, for example Bechtel and CH2M Hill Constructors/IDC; public and private Owners, including the Federal Government of the United States of America; and academic institutions including Oregon State University. The mission of the CII as stated on their website[83] is:

> "The mission of the Construction Industry Institute is to improve the business effectiveness of the capital facilities life cycle, including safety, quality, schedule, cost, security, reliability, and operability. Participation in CII provides members the opportunity for a competitive advantage in the global marketplace."

In the 1990's the CII undertook a "Benchmarking" project to evaluate "Best Practices" in the Construction Industry resulting in a series of reports including: [207]. The most recent most recent version or update prefaces the report with the following statements:

> "The report presents the compilation of data analyses performed in early 2000 using the Construction Industry Institute (CII) Benchmarking and Metrics (BM&M) database."

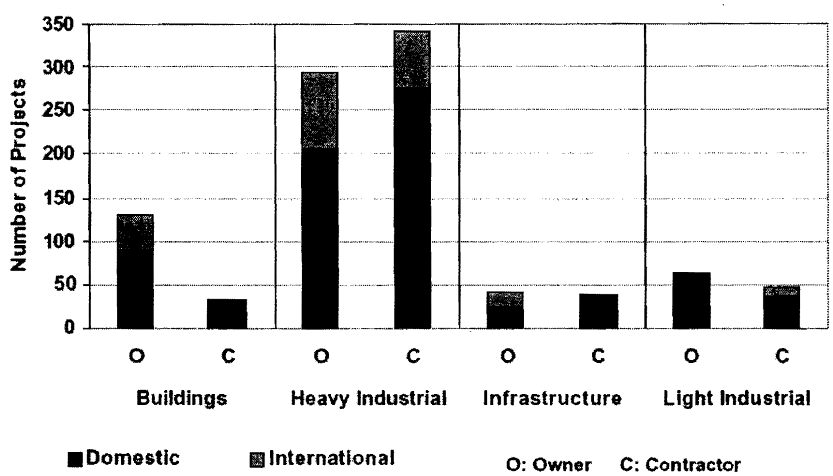
> "Data included in the report were collected through February 4, 2000. The purpose of the report is to establish an authoritative source of information providing norms for project performance and practice use metrics. Performance norms are provided for cost, schedule, safety, changes, and rework. Practice use metrics are included for pre-project planning, constructability, team building, zero accidents, change management, and design/information technology best practices. In addition, norms for percent design completion at authorization and construction start are included. Data on each of these practices have been collected for at least 3 consecutive years. Additional practices are being added in an on-going effort to establish the level of use and value of all CII recommended best practices."

This recent version of the Benchmarking Report is produced on Compact Digital Disk or CD [51] and contains more than 3000 pages of description and analysis. The

[82] See: http://construction-institute.org/services/catalog/products/pr_pro.cfm#8.5 for specific products.

[83] See: http://construction-institute.org/

current version includes $52.2 billion in construction on 989 projects reported by 33 Contractors and 39 Owners. However, the CII database is heavily weighted to "Industrial Projects" as seen in Figure 33, with fewer than 100 domestic building project reported by Owners and fewer than 50 reported by Contractors. Chemical Manufacturing (225) and Oil Refining (158) make up the two single largest categories of project types in the CII database. By contrast there are only two (2) prisons, four (4) parking garages, three (3) housing projects and thirteen (13) schools represented in the CII database[84].



	Buildings		Heavy Industrial		Infrastructure		Light Industrial	
	O	C	O	C	O	C	O	C
International	40	3	86	67	17	3	2	11
Domestic	90	31	208	275	25	35	61	35

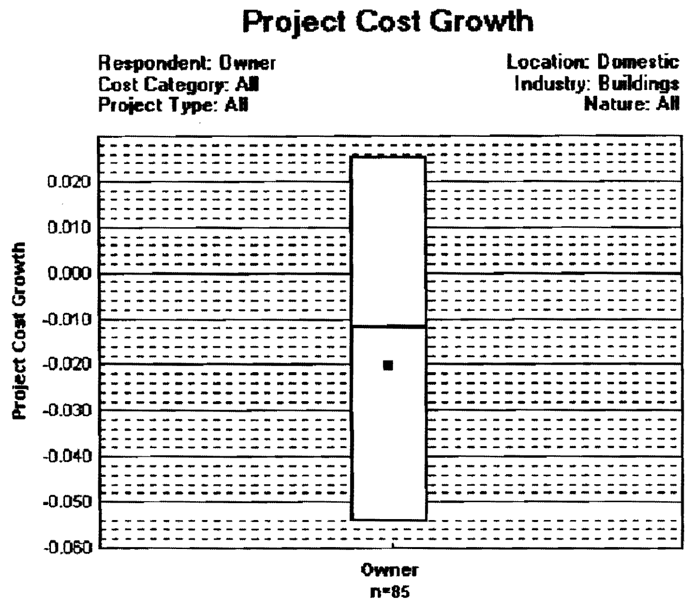
O- Owner
C- Contractor

Figure 33: CII Benchmarking Report [51] Project Type Figure #3

One significant advantage the CII has in its research is the fact that its members agree to supply the CII research team with very sensitive information[85] because all of the data is kept strictly confidential[86]. In addition to having access to a lot of data the Institute's efforts are well funded, as each member pays annual dues of $36,000 per year according to their website information on Membership.

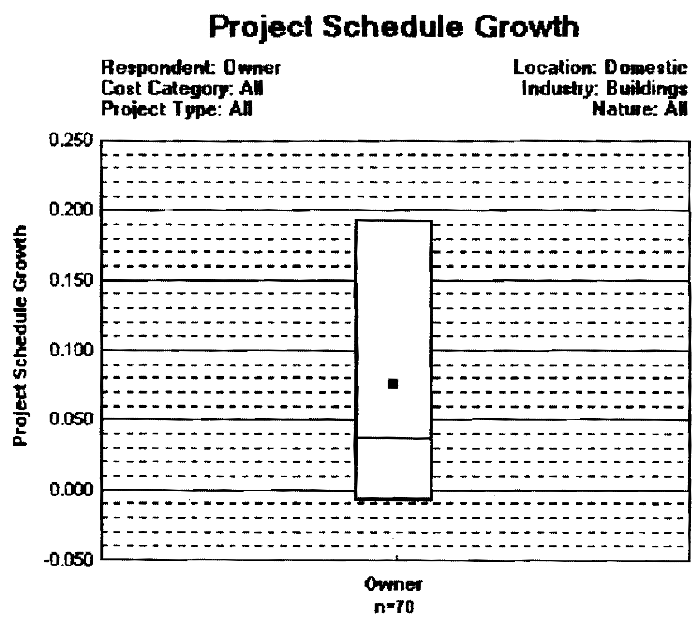
[84] The Oregon database of public projects includes a large number of school buildings, which are the most commonly constructed public projects.
[85] Safety and accident information, while required by OSHA is not "Public" information that can be obtained without the consent of the contractor.
[86] We made several attempts to obtain the CII Benchmarking Database raw data in any form that would have been acceptable to the CII, but the CII has not released that information.

Typical of the CII report are analysis of overall project cost and schedule growth such as is presented in Figure 34 through Figure 37 for Domestic Project Cost and Schedule Growth, reported by Owners and Contractor's.



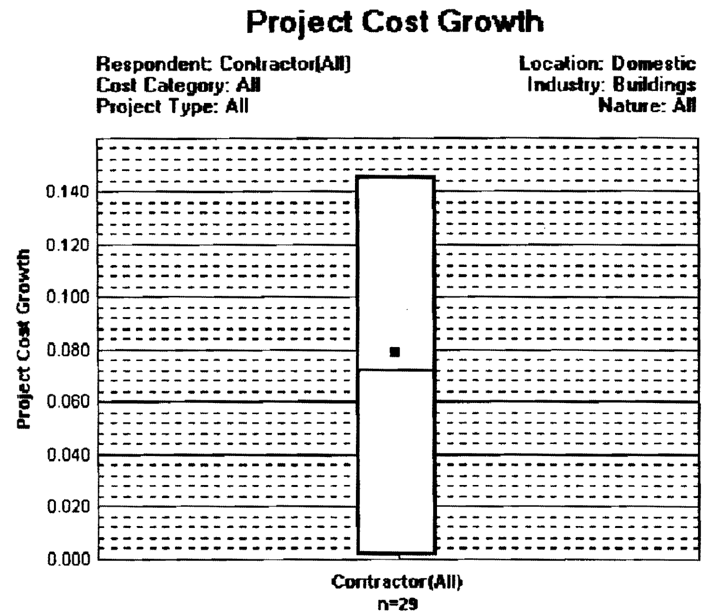
	Owner
Best	-0.325
100%	0.203
75%	0.025
50%	-0.012
25%	-0.054
0%	-0.277
Mean	-0.020
SD	0.084
n	85

Figure 34: CII Benchmarking Report [51] Domestic Project Cost Growth Figure #765



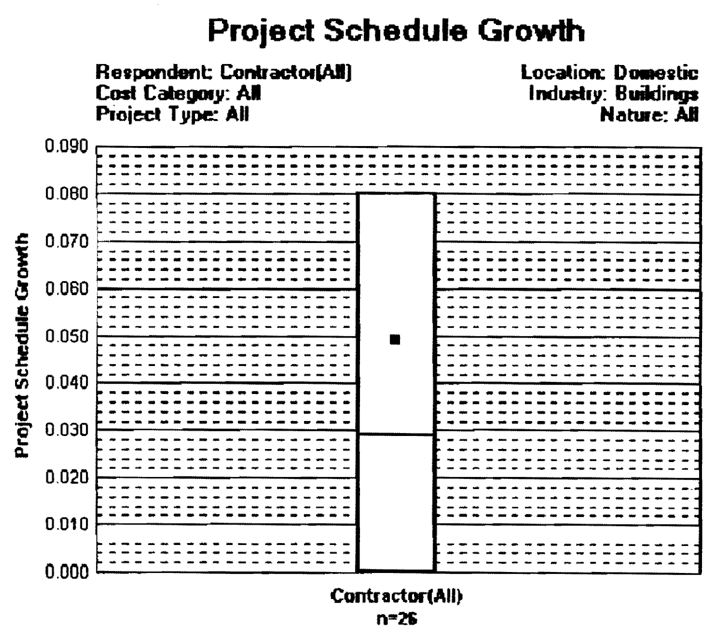
	Owner
Best	-0.323
100%	0.473
75%	0.192
50%	0.037
25%	-0.007
0%	-0.323
Mean	0.076
SD	0.166
n	70

Figure 35: CII Benchmarking Study [51] Domestic Project Schedule Growth Figure #859



	Contractor(All)
Best	-0.120
100%	0.330
75%	0.145
50%	0.072
25%	0.002
0%	-0.120
Mean	0.079
SD	0.104
n	29

Figure 36: CII Benchmarking Study [51] Domestic Project Cost Growth Figure #1310



	Contractor(All)
Best	-0.136
100%	0.324
75%	0.080
50%	0.029
25%	0.000
0%	-0.136
Mean	0.049
SD	0.110
n	26

Figure 37: CII Benchmarking Study [51] Domestic Project Schedule Growth Figure #1375

On Domestic Building Projects, that include both private and public projects, the CII study found that the Owner's experienced a mean cost reduction of 2.0%, and a Project Schedule Growth of 7.6%, while Contractor's reported mean Cost Growth on Domestic Building Projects to be 7.9% and mean Project Schedule Growth of 4.9%. It should be noted that the Owner's and Contractor's are actually reporting different things because the Owner's "Project" is generally more broad than the Contractor's, including such things as land acquisition, planning and design through construction and commissioning; whereas the Contractor's involvement may be limited to just the "construction" portion of the job. This is explained in the, "Metrics Definitions" section of the report. The important thing to note here is that the CII Study found both Cost and Schedule Growth in the Contractor's reports and Schedule Growth in the Owner's reporting. The Contractor's reports ranged from a Project Cost reduction of -12.0% to a Cost Growth of 33.0%, and a Project Schedule reduction of -13.6% to a Project Schedule Growth of 32.4%.

The CII study [51] includes statistical analysis of Project Safety using Recordable Incident Reports, Project "Rework" (which is a measure of quality) and various "Practice Use's" including: Team Building, Pre-Project Planning, Design/Information Technology, Project Change Management, Planning for Start-up, and Materials Management. These latter metrics are generally measured using a 1 to 10 rating scale contained in surveys filled out by different project personnel. It would be difficult to replicate the CII's effort here, in that their member organizations had to agree up-front, to training project team members in the proper way to fill out these rather extensive reports in a consistent manner.

Finally, this most recent Benchmarking Report [51] did not replicate the linear regression benchmarking analysis performed in earlier versions (as noted in [207]) and the reason the CII apparently abandoned that analysis is not known. In any case, the uni-variant statistical analysis contained in this benchmarking report will provide a good independent check against our own findings from the Oregon database for similar metrics.

CII Project Delivery Systems Reports #133 & #133-1

In 1997 the CII published the first of two companion studies evaluating Project Delivery Systems [75], which lists the Design-Build Research Team as author. The second study [183], authored by Sanvido and Konchar[87] is in fact the basis for the former report, which is listed as a "Research Summary" (the former is CII Report #133-1 and the latter is #133, also the same study is published in [126].) The reports (and [126]) draw identical conclusions although the earlier report [75] is more forthright in it's Executive Summary, stating:

> "The research shows that design-build systems have significantly less design and construction cost growth when compared to design-bid-build; that design-bid-build systems have the greatest design and construction schedule growth; and that quality measurement associated with design-build, often maligned by many, is better than quality performance in design-bid-build."

[87] Konchar also presented the results of this research at the Northwest Construction Consumers Fall 1999 Conference, "Advantage 2000" in a "Copyrighted" presentation [127]

Although the report does add the caveat:

> No one method can meet all owner, project, or individual critical success factors. Any delivery system is dependent on the ever-changing dynamics of our industry. Now, however, there are statistically analyzed results that will improve the owners' ability for selection. Those results are the subject of this report.

The second report [183], is a bit more cautious in its Executive Summary, however the report concludes in its Chapter 7: Conclusions and Recommendations:

> "Design-build *unit cost* was at least 4.5 percent less than [CM/GC] and six percent less than design-bid-build. In addition, construction management at risk unit cost was at least 1.5 percent less than design-bid-build. This model explained 99 percent of the variation in unit cost.
>
> Design-build *construction speed* was at least seven percent faster than [CM/GC] and 12 percent faster than design-bid-build. In addition, construction management at risk construction speed was at least 6 percent faster than design-bid-build. This model explained 89 percent of the variation in construction speed.
>
> Design-build *delivery speed* was at least 23 percent faster than construction management at risk and 33 percent faster than design-bid-build. In addition, [CM/GC] delivery speed was at least 13 percent faster than design-bid-build. This model explained 88 percent of the variation in delivery speed.
>
> This research has clearly shown that there are differences between these systems. Design-build offers more speed and more certainty in cost and schedule than does design-bid-build. However, design-build may not be suited for every situation or each facility type. Likewise, construction management at risk offers more speed than does design-bid-build. It is understood that design-bid-build may be better suited for specific projects, yet it did not offer superior performance on a repeatable basis in any area measured by this research."

The author's conclusions are supported by the following summary of the multivariate statistical analysis:

Multivariate Model Analysis for:	No. of Cases used: No. with missing values	Adjusted R^2 of the Model
Regression for Unit Cost	203 : 144	99.0%
Regression for Construction Speed	329 : 20	88.1%
Regression for Delivery Speed	328 : 22	86.4%
Regression for Cost Growth	196 : 152	11.7%
Regression for Schedule Growth	215 : 132	14.4%

Table 27: Summary of CII Report #133 Data

The interesting fact is that the three models with very high adjusted R^2 values: Unit Cost, Construction Speed and Delivery Speed may not have much importance in the public building sector and in fact these metrics and measures may be correlated with project type and PDS. For example, Project Delivery Speed takes into account the total time from beginning of design to commissioning of the project. However, the CII Project Database is heavily weighted toward heavy industrial projects like chemical plants where design-build PDS is quite common and where DBB PDS's may be very difficult to implement. Furthermore, since the definition of design-build (and CM/GC for that matter) is a project where the construction starts before design in 100% complete, it should be a foregone conclusion that they should be delivered faster. More troubling however is the fact that the most important Models: Schedule and Cost Growth show the least significance. Another important consideration, which is not addressed in the above analysis is whether these "statistically significant" differences are really important differences [209], or whether they are merely structural aberrations of the PDS's.

Sanvido and Konchar discuss "Univariate Comparisons" in [183] in Section 4.5.1, page 49, and state on page 50 that:

> "Descriptive statistics offer ways to measure the central tendency of a large data set. Measures such as the mean, median, variance and ranges of several metrics calculated from project data were used as initial comparisons. However, the common statistical assumption of normally distributed samples was clearly inappropriate. The initial analysis of central tendency quickly confirmed that mean, median and mode values were very different, thus indicating the need for a battery of tests. Therefore, detailed hypothesis testing was required to make conclusions about the significance of differences between delivery system performance."

> "Hypothesis testing measured the strength of evidence in the data for or against precise statements about population characteristics. The first hypothesis testing used two sample t-tests based on sample means. For example, the tests used to compare delivery systems in terms of cost growth, indicated the level of significance with which the researcher could claim one delivery system was performing differently than another. Hypothesis testing for sample medians was also chosen. Mood's median test was used because it

effectively adjusts for outliers in data, and is particularly appropriate in the preliminary stages of analysis (Minitab, 1995). Working together, two sample t-tests and Mood's median tests allowed the researcher to test significance between a number of critical metrics."

These univariate results are presented in Chapter 6 of [183] and Chapter 2 of [75]. The report summarizes this analysis in the following figures:

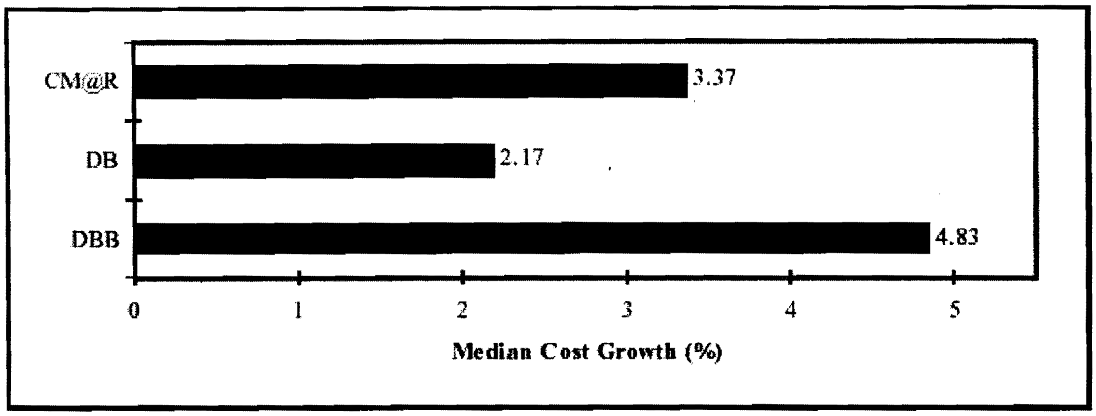


Figure 38: CII Report #133 Figure 6.5 Median Cost Growth comparisons

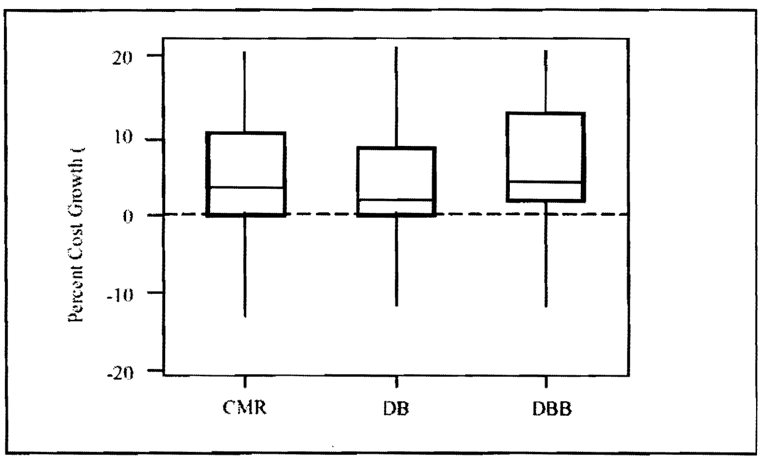


Figure 39: CII Report #133 Figure 6.6 Cost Growth Comparisons

CII interprets the results from Figure 38 and Figure 39 as:

"Here design-build projects, had less cost growth than either construction management at risk or design-bid-build. However, results indicated that both construction management at risk (0.029, 0.008) and design-build (0.007, 0.008) significantly outperformed design-bid-build in terms of sample cost growth. The maximum standard error for cost growth was plus or minus 2.2 percent."

And:

"The bottom and top of the each box indicates the upper and lower quartiles of each sample. This reports that 25 percent of all design-bid-build and construction management at risk projects experience cost growth over 10 percent. Conversely, 25 percent of design-build and construction management at risk projects fall at or below zero cost growth, indicating that the likelihood for cost growth using these systems is slightly less than that using design-bid-build."

However, an alternate, and perhaps more interesting observation of the data presented above is the fact that 75% of both the CMR (or CM/GC) and DB projects and 90% of the DBB projects experienced "Cost Growth." Since the authors indicate that they only address differences that are statistically significant at the 95% level, and they do not discuss the difference between CMR and DB on the Cost Growth metric, we are left to conclude that the two are not significantly different, in spite of the statement that, "DB projects, had less cost growth than either CMR or DBB." Furthermore, the extreme points, which represent the outside or maximum risk are not significantly different according to these box-plots.

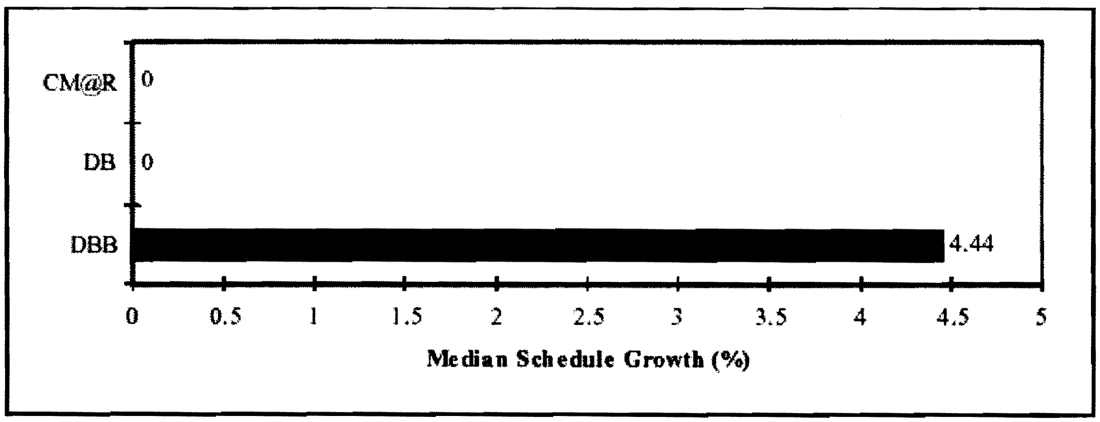


Figure 40: CII Report #133 Figure 6.8 Median Schedule Growth comparisons

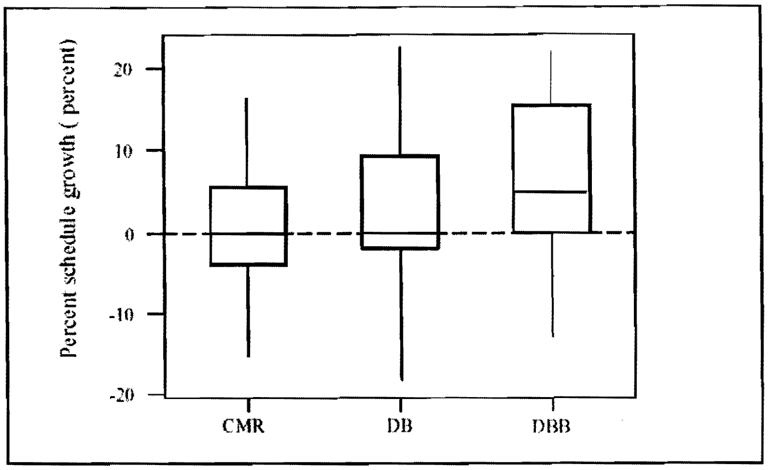


Figure 41: CII Report #133 Figure 6.9 Schedule Growth comparisons

The CII interpretation of Figure 40 and Figure 41 observed that:

> Both design-build (0.03, 0.0) and construction management at risk (0.008, 0.0) significantly outperformed design-bid-build in terms of schedule growth. The maximum standard error for schedule growth was plus or minus 1.7 percent.

And:

> Figure 6.9 shows representative box-plots for schedule growth by delivery system. The distribution of each sample shows, in greater detail, the consistent schedule performance of construction management at risk and design-build. Fifty percent of all construction management at risk and design-build projects fell below zero percent schedule growth. This represents an area of significant difference over the performance of design-bid-build, where 50 percent of the projects were more than four percent late in completion.

Again, over 50% of both CMR and DB projects experienced schedule growth, and 75% of DBB projects took longer than scheduled. And, while it appears that CMR does better than DB on this metric overall, the difference was apparently not significant, whereas both CMR and DB performed significantly better than DBB. The report does not give the Mean of the data nor does it discuss the fact that the box-plot for CMR indicates that the maximum risk of project increase or decrease in schedule growth was less than both DB and DBB. Furthermore, DB appears to fair worst of all in terms of maximum outside risk of project both being finished ahead of schedule and late. The use of the "Median" instead of the Mean here may tend to hide the fact that DB may riskier than both CMR and DBB in terms of schedule growth.

The one thing missing from this analysis however is any mention of the fact that in both the DB and CMR projects, the Contractor has significant input on the initial project budget and schedule that is not available in the DBB case. In fact, it is not surprising that

DB projects do significantly better on schedule performance because the DB Contractor usually decides on or dictates to the Owner, the original project schedule. The fact that the differences are so slight, as depicted in Figure 39 and Figure 41 is perhaps a reason for caution.

One of the principle concerns about Design-Build projects has been "Project Quality" because a fixed price Design-Build Contractor has an incentive to "design out" expensive design components as the project nears completion and the budget nears exhaustion; although, Project Quality is not one of the prominent criticisms of Design-Build PDS in [139]. In any case Project Quality is one of the three pillars that most people think of when they think of construction measures: Time, Cost and Quality. Here the authors acknowledge that:

"The nature of quality data was less objective than other principal metrics."

In spite of the fact that some objective, "Project Quality" measures like: number of punch list items[88], number or dollar amount of warranty work performed, could be collected, the authors decided to have the Project Owner's rate the quality on a relative scale. Unfortunately however, the relative rating scale included measuring the perceived actual level of quality compared with the level expected. This type of measure would tend to bias in favor of low expectations. If an Owner expected the project to be pathetic and it turned out only lousy, perhaps he rate it high relative to his initial very low expectations. Conversely, if the initial expectations were extremely high, it is doubtful that a Contractor, under any PDS could produce a very high rating relative to a very high expectation.

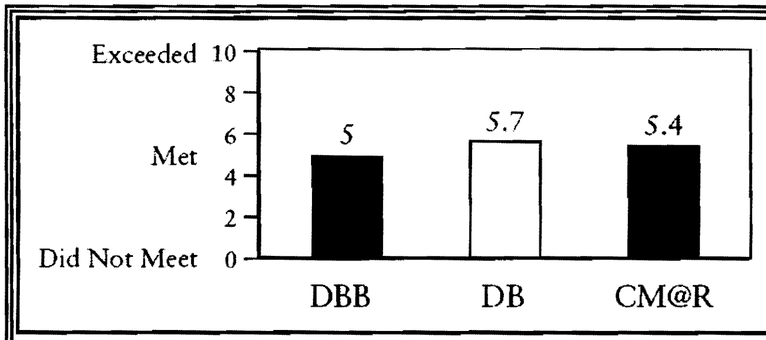


Figure 2.13. Quality – System Performance
Expectations of Envelope, Roof, Structure and Foundation

Figure 42: CII Report #133-1 Figure 2.1.3 Quality

[88] Number of square feet constructed per punch list item was the measure of quality used in the research on the Oregon projects DEA model discussed in Section 4.

In addition to the bias toward low expectations, the difference between the different PDS's as seen in Figure 42 are not terribly great in terms of overall percentage difference, and it's unclear if these different means were statistically significant. Nevertheless, the authors point to these statistics and other similar analysis to conclude that DB out-performs DBB and depending on the metric, CM@R (what we call CM/GC) stating:

> "It is clear from these results that design-build projects achieved equal if not better quality results than other projects studied. In particular, design-build offered significantly better quality results than design-bid-build in all categories except that of interior space and layout. Design-build significantly outperformed construction management at risk in only one area, operation and maintenance cost."

At least in part based on the following figure:

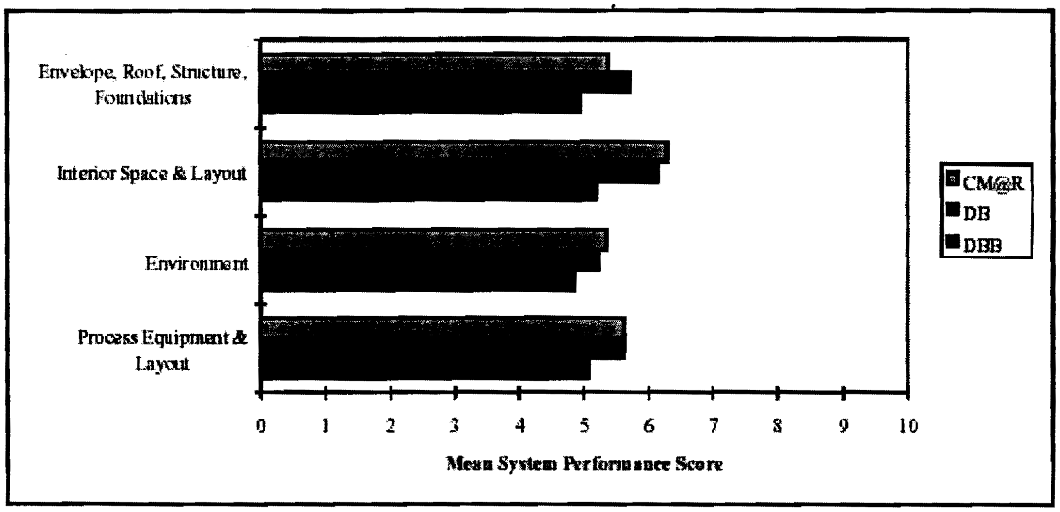


Figure 43: CII Report #133.1 Figure 6.15

It should be noted that on three of the five system performance quality scores shown in Figure 43, CM@R (or CM/GC) performs as well or better then DB, whereas, DBB always performs worst. However, the difference between best and worst in most of the comparisons appears to be very little, whether statistically significant or not, it does not appear to have practical significance, particularly in light of the fact that these are measures of relative subjective expectations as opposed to objective data measures.

Northwest Construction Consumer Council "Advantage 2000"

In September 1999 the Northwest Construction Consumer Council, an organization made up of principally large public and private institutional facility and building owners and large construction contractors held its fall conference on the topic of Project Delivery Systems. Dr. Mark Konchar presented the results of [183] in [127] and Mr. Jon C. Vanden

Bosch presented a similar study [210], titled "Comparing Project Delivery Systems." His study, which had its beginnings in 1996, used a survey questionnaire sent out to collect data on over 7,600 projects, more than 400 were actually returned and 351 were used in the analysis.

The Vanden Bosch paper [210] was lead by some of the main Design-Build Research Team members that produced [75], including Dr. Sanvido and Norman L. Strong (an executive with Marshall Contractors and CII Research Team Chairman). This research focused on Cost, Schedule and Quality metrics, acknowledging the difficult task of defining and comparing project Quality.

Vanden Bosch reports exactly the same results as does [75] and [183], and uses the same number, 351 projects in the analysis. However, there is no mention of the more than 7,600 surveys questionnaires in [183 323] or any mention of Vanden Bosch. In any case it is a reasonable conclusion that the [210], [75], and [183] studies are all using the same underlying data and consequently each reached essentially the same result.

As a final note on the CII studies, [183] and [75]: the authors felt compelled to include a section in their report: 4.6.3 Research Team Bias, wherein they state:

> "The researcher exhibited no bias toward the delivery systems investigated in this study primarily due to a lack of extensive experience using each method."

However one Expert Panel Member for this research, familiar with the CII studies and a member of the Northwest Construction Consumer Council, anonymously commented that "the Design-Build Institute paid for a study that showed that Design-Build was the best Project Delivery System, and that's what they got." He added that both principal authors of [183] were currently or recently employed by large Design-Build Contractors or the Design-Build Institute. Whether this colored their analysis or not, the fact is that the claims made that Design-Build is a significantly better PDS than CM/GC and DBB, and that CM/GC is better than DBB, do not appear to be supported by their research. And the only metrics that do support that conclusion are structurally biased to do so.

One thing is clear however, [183] does an excellent job of defining the issues, researching the literature (albeit heavily weighted to the Design-Build research) and defining the systems, coming up with measurable metrics and defining terms.

Project Delivery System Selection Workbook CII Report #133-2

The CII produced a Workbook intended to help Owners determine which PDS is appropriate for their project and propose the use of the following data collection sheet, depicted in Figure 44:

Name of project: ________________ ***Type of facility:*** ________________	Level of Importance: More Important				Less Important	Score (Sum)	Rank (1-8)
Unit Cost							
Final square foot cost is critical on this project.	5	4	3	2	1		
The square foot cost is critical to owner's profitability.	5	4	3	2	1		
Construction speed							
The duration of construction time is critical to you.	5	4	3	2	1		
The schedule demands a short construction period.	5	4	3	2	1		
Delivery speed							
Your facility produces products that must get to market rapidly.	5	4	3	2	1		
The duration of design and construction time is critical to you.	5	4	3	2	1		
Cost Growth							
Funding is limited to the contract costs and a small contingency.	5	4	3	2	1		
The certainty of completion on budget is critical.	5	4	3	2	1		
Schedule Growth							
The certainty of completion on schedule is critical.	5	4	3	2	1		
Your business obligations require occupying the facility on time.	5	4	3	2	1		
Turnover quality							
The facility startup process is critical to your business.	5	4	3	2	1		
Your operation cannot tolerate impacts from many callbacks.	5	4	3	2	1		
System quality							
Performance of MEP systems are critical to your business.	5	4	3	2	1		
Quality of the envelope and architecture is critical.	5	4	3	2	1		
Process equipment quality							
The performance of process equipment is critical to your business.	5	4	3	2	1		
The layout of process equipment is critical to your business.	5	4	3	2	1		

Figure 44: CII Report #133-2 Figure 2 Critical Project Goals

However, the authors repeat the findings from Report #133 [75], as Summarized in Table 27 above, but in Table 28 below, they include the average differences between the PDS's based on [75], using the R2, as opposed to the Adjusted R2 values summarized above.

Metric	DB vs. CMR	CMR vs. DBB	DB vs. DBB	Level of Certainty
	%	%	%	%
Unit Cost	4.5 less	1.5 less	6 less	99
Construction Speed	7.0 faster	6.0 faster	12 faster	89
Delivery Speed	23 faster	13 faster	33 faster	87
Cost Growth	13 less	7.8 greater	5.2 less	24
Schedule Growth	2.2 less	9.2 less	11 less	24

Table 28: CII Report #133-2 Table 2, Summary of Average Performance Comparisons of PDS's

It would appear from Table 28 that the only rational choice for an Owner would be to use DB for their PDS, since DB is superior to both DBB and CMR on every category measured, of course the Level of Certainty is extremely low on two important metrics of Cost and Schedule Growth[89]. The same criticisms discussed in *0* regarding Table 27 and its underlying analysis contained [75] are relevant here also. Specifically, that the DB contractor has significantly more control over the all of the metrics since the DB contractor, in most cases, has a significant decision making capacity relative to scope, cost, quality, and schedule factors, which the DBB contractor has virtually no control over, and the CMR contractor may have some but little impact on. Again, those aspects of the PDS differences are omitted from the report.

[89] See the discussion following Table 27 in Section 0 above, note that in Table 27 Adjusted R^2 is reported, here the unadjusted R^2 is used, based on the same data – this is consistent with a similar table in [75]. Devore [78] notes that "many statisticians use the Adjusted [R^2]," "to balance against the cost of using more parameters against the gain in R^2. Why the authors chose to use the R^2 instead is a unknown since the adjusted R^2 readily available from the statistical program output found in the report.

Washington State Alternative Public Works Methods Oversight Committee Study

This study published December 11, 2000, was required by the Washington State Legislature when it enacted the legislation authorizing the use of non-lump sum bid PDS's in the State of Washington. The legislation in Washington is different than that enacted in Oregon, with more restrictions placed on public agencies than in Oregon. However, the actual form of contract and PDS resulting from its application is essentially the same and this review Report serves to add to the understanding of the benefits and drawbacks of the CM/GC contracting.[90]

The Report unfortunately falls short of a thorough evaluation of the processes used in Washington because it fails to present any objective data analysis and appears to discount any negative comments in the subjective analysis. The Report honestly concludes in its Executive Summary that: "[CM/GC] project participants strongly endorse the [CM/GC] process across all aspects and throughout all phases of their project." Honest, because it tacitly acknowledges that it reflects only the voices of the supporters and not the critics or those that were excluded from project participation, because as seen in the "competitor comments" the disappointed contractors were not as enthusiastic about the process as practiced in Washington state.

The Report, received about 10% response rate on the CM/GC portion and 7% on the DB portion, but fails to acknowledge that these responses may have been positively biased. The Report focused solely on 49 CM/GC projects and made no effort to objectively compare them against similar DBB projects and provides little objective data. Only 30 of the 217 returned surveys (out of 2107 sent out) were from subcontractors who actually performed the work. And "8 contractors that competed for [CM/GC] projects returned 52 contractor competitor surveys" meaning that 8 contractor's accounted for nearly one quarter of all responses. Left unsaid in the Report is whether or not these were successful or disappointed proposer's, but indications from the survey comments is that these were generally the successful CM/GC Contractors[91]. The largest single group of respondents, surprisingly enough were government employees, a 65% response rate, as opposed to a 5% from subcontractors who actually performed the work. The problem here is that the public agency Owner is the construction team member that actually got to decide what PDS to use. It seems unlikely that the Owner's project manager would then criticize his or her own decision to use CM/GC instead of DBB. Furthermore, it is generally recognized that CM/GC contractual relationships are less confrontational and adversarial; benefits that accrue directly to the Owner's project management team. But the real question is not whether or not the process makes the Owner's project manager's task easier or more palatable, but rather is it better for the taxpayers? Clearly if reducing confrontation

[90] In Washington it is referred to as GC/CM, which means: "General Contractor/Construction Manager" or some times CM/GC which means: "Construction Manager" with a "Guaranteed Maximum Price," both are the same thing as CM/GC used in Oregon.

[91] In fact more than one comment stated that the project was not yet complete, meaning that they were obviously working on the job, therefore the successful Contractor.

and the adversarial nature of DBB contracts were the ultimate goal, that could be achieved by simply giving the Contractor every change order asked for without question.

One important piece of information contained in the Report is the following graph:

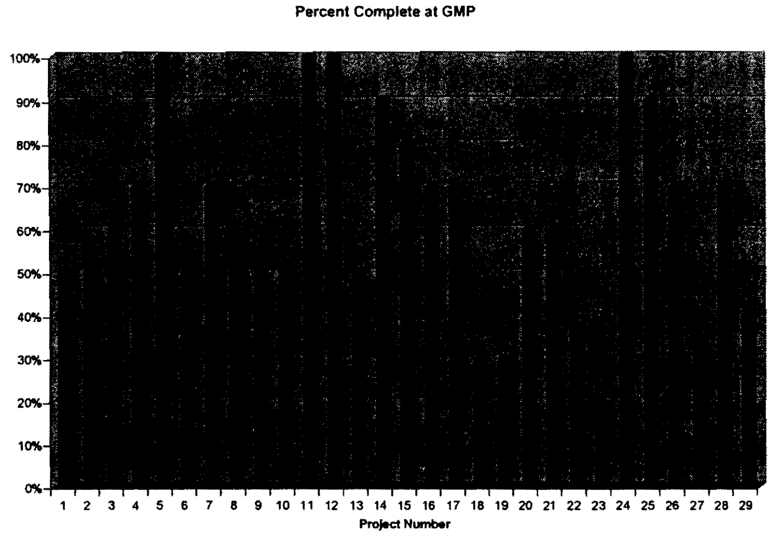


Figure 45: Percentage of Design when Guaranteed Maximum Price is established

This information is valuable in comparing Washington state's experience against those obtained from Oregon. Based on the Oregon database results, it appears that the Washington projects were similarly distributed with very few projects priced while in conceptual phases, more during schematic design, and still more during preliminary design phases. The biggest difference is the number of projects that are at final design stage (100% complete) prior to pricing. In Washington that proportion is about ten percent of all CM/GC projects, the proportion of Oregon CM/GC projects priced at this stage is significantly less.

Another bit of objective data is contained in the following figure:

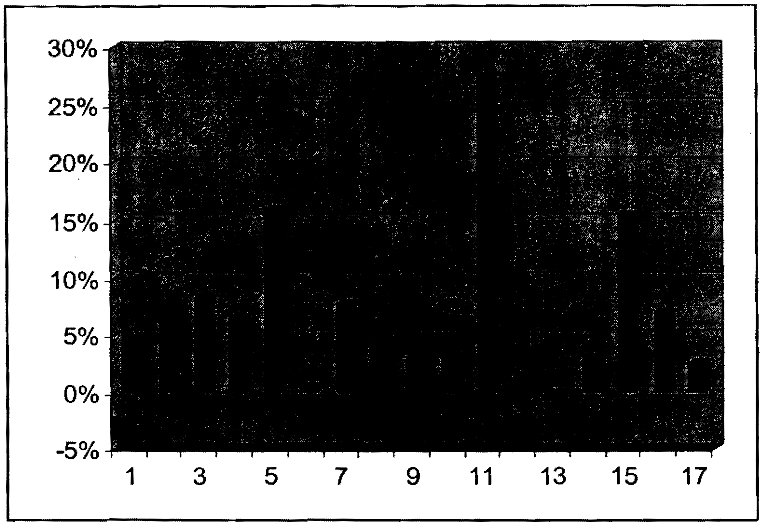


Figure 46: Washington Report % Change Orders

Figure 46 documents Change Order costs as a percentage of the total project cost on the CM/GC projects in the Washington Report. Note that this includes only seventeen (17) of the forty-one (41) projects reviewed, the inference being that the other projects did not report financial metrics. In any case, the average CM/GC project had a cost increase of 7.2% and a standard deviation of 7.09%, which closely compares with the CII studies discussed above (in particular see the results documented in Figure 36 of the Benchmarking Study.

Appendix F: ORS 279.103 Evaluation Reports and Project Audits

This appendix presents our complete discussion regarding the actual project reports on CM/GC jobs in Oregon. These evaluation reports are required by statute (ORS 279.103) in Oregon for all projects exempted under Chapter 279. However, very few public agencies have complied with the statute and few of the reports meet the objective analysis standard intended by the legislature. Following the evaluation reports, there are project audits from Oregon's Secretary of State of specific CM/GC projects. Many of these audited projects are the same projects that the evaluation reports covered. In several cases there are striking differences in how the projects were viewed by the different authors.

ORS 279.103 Reports

The Oregon PCC Report [56] documents the requirements under ORS 279.103 and gives recommendations on how to comply with the statute as follows:

> The purpose of the ORS 279.103 evaluation is to determine whether it was actually in the public's best interest to use an alternative contracting method. The following elements are required by the statute to be included in the evaluation:
>
> - Financial Information consisting of cost estimates, any guaranteed maximum price, changes, and actual costs.
> - The number of project change orders issued by the public agency.
> - A narrative description of successes and failures during design, engineering, and construction of the project.
> - An objective assessment of the use of the alternative contracting method as compared to the exemption findings required by ORS 279.015.
>
> An effective way to present the required report is to simply comment, point by point, on each statement made in the original project exemption findings. In addition, to the above requirements, evaluation reports are to be made available for public inspection and must be completed within 30 days of the date that the public agency accepts the public improvement project. The report is to be delivered to the Director of the Oregon Department of Administrative Services or the local contract review board.

Unfortunately, to date, no one at the Department of Administrative Services is directly responsible for collecting these reports nor is any person, including anyone in the Director's office, aware of whether any such reports exist or are kept. An attempt was made to collect as many 279.103 Reports as could be found by contacting agencies known to have used CM/GC since the law went into effect. Only the Oregon Department of Corrections has made a great effort to comply with the law, with other agencies like the

Port of Portland, for all intents and purposes, ignoring the requirements all together[92]. Others, like Central Oregon Community College have paid the requirement only lip-service by parroting their own findings reports with affirmative responses devoid of any "objective analysis" or data.

Oregon Department of Corrections (DOC)

The Oregon DOC undertook a large building program in 1995, following the passage of Ballot Measure 11 in November 1994, which required longer prison sentences thus requiring more beds. Three new large prisons were constructed using the CM/GC PDS, and consistent with the requirements of ORS 279.103, the DOC published reports assessing the performance of the projects relative to the original exemption criteria, the project successes and lessons learned during the projects.

Snake River Correctional Institution Phase II (SRCI)

According to the Department of Corrections [168], the SRCI at $175 million, was "the single largest single public works project at that time in the history of the State of Oregon." The project included 802,000 Gross Square Feet and had total construction costs of $151,805,477 (on an original GMP of $144,036,000 after two Change Orders amended the Contract price). The total amount spent by the State on the project, including all design, project management, administrative and construction costs, was $174,954,384. The total project budget is summarized in:

[92] Mr. Tom Peterson, the Port's Director of Engineering has promised to have these reports up to date, but that promise made in the fall of 2002 remains un kept, and as late as May 2003 he has not had the staff available to do the work, in spite of the fact that at least two major CM/GC projects were finished in 2002.

Item	Original Budget	Final Cost	Variance
CM/GC GMP	$144,036,000	$142,292,956	$1,743,044
Amendment 2 (Change Order 1)	$7,816,155	$7,816,155	$0
Amendment 3 (Change Order 2)	$1,696,322	$1,696,322	$0
Subtotal (Total GMP)	$153,548,477	$151,805,433	$1,743,044
Miscellaneous Construction/ Support			
ODOC Provided Projects/ Management	$5,443,260	$4,406,025	$1,037,235
Consultants			
HOK (Architect)	$9,100,000	$9,681,000	<$581,000>
CRSSC (Project Management)	$0	$2,499,227	<$2,499,227>
AGRA (Special Inspections)	$720,180	$1,083,655	<$363,475>
Subtotal	$9,820,180	$13,263,882	<$3,443,702>
Offsite Costs			
Idaho Power (Electrical)	$0	$28,078	<$28,078>
Irrigation	$0	$2,154	<$2,154>
Domestic Water	$2,200,000	$1,070,594	$1,129,406
Sanitary Sewer	$3,942,467	$4,336,524	<$394,057>
City of Ontario Community Impact Study	$0	$6,288	<$6,288>
Subtotal	$6,142,467	$5,443,638	$698,829
PROJECT TOTAL	**$174,954,384**	**$174,918,978**	**$35,406**

Table 29: Project Summary from [168]

Note that the "Final Cost" under the CM/GC GMP actually shows a savings of $1,743,044. This takes into account the Change Orders in the GMP; in short, the CM/GC was actually paid about $142 million for the original $144 million scope of work under the GMP (Guaranteed Maximum Price), an additional $9.5 million of project scope, not in the original GMP was added to the GMP, raising the final adjusted GMP to $153,548,477.

The report describes the overall project experience and use of the CM/GC process on the project as follows:

> "The SRCI Phase II expansion project presented various unique and complicated challenges requiring intense management review and effort. The complicated logistics of staging a major construction project within an existing secure facility and the pressing need for beds necessitated a delivery process that allowed close collaboration between the architect/engineer and the

contractor during design; a single point of responsible communication for decision-making purposes between ODOC and construction operators; and reduction of the financial risk for ODOC. As a result, the ODOC subsequently chose and managed the CM/GC process to successfully complete the project within budget and within schedule"

Note again that the project was considered "within budget and within schedule." Of course it is clear that the original GMP or construction estimate prepared by the CM/GC and including an Owner controlled contingency, was not met. However, according to the report, this was at least in part due to the fact that the project had undergone a scope reduction during the early planning and estimating stages. During the CM/GC process, the scope "was made whole again thorough the project team's value engineering and constructability reviews."

The report listed a number of challenges faced by the project team in this project, which in part justifies the use of a CM/GC PDS on the project:

- Infancy of the new prison construction program
- Project Size
- Schedule Requirements – Fast Track Construction
- Security Requirements associated with inmate work program goals
- Phased Construction at an existing institution

The report documents significant project successes, including the use of "fast track" construction, value engineering, use of inmate labor, twenty-two months and 700,000 man-hours without a lost time accident, zero outstanding claims[93], no breaches in security, and successful involvement with the local business community. Under the "Lessons Learned" section of the report, the author notes the following:

"As is the case in all construction projects, lessons can be learned after reviewing the successes and failures of the project. The CM/GC process was selected for this project because of the advantages it offered for 'fast tracking' construction and reducing risk to the Owner. By identifying instances where cost of work was adjusted upward in the SRCI project, ODOC has obtained invaluable information necessary to improve the way they utilize the CM/GC process on future projects.

Dedicate adequate time and resources to design and constructability reviews during the design development phase of the project and the subsequent issuance of bid packages. Dedicating additional time and resources by all Project Team members during this important phase will enhance both the quality of the final design bid documents and quantity of work procured

[93] Although there were substantial subcontractor claims on the project, these were negotiated to settlement prior to the end of the project for a total of $1,060,100, which was about 20% of the original claim total.

through the Project's competitive bid process and fewer expensive change orders. As a result of the "fast track" design and construction process used on this Project, the typical design and review time of a Project this size was substantially shortened. This reduction in design and review time resulted in certain systems and components being issued for competitive bid before they were fully designed and/or integrated with other work.

Insure that departmental "end-users" are actively involved in the design development review process. In reviewing the work secured after the initial competitive bid packages were awarded, it appears that additional efforts need to be made to insure "end-users" are more actively involved in the design development review processes. With the likelihood that operational personnel will not be experts on the design development review process or details of overall systems, additional effort needs to be made to explain these systems to them in plain language during regular design reviews leading to a more complete understanding and support of design by "end-users." Resulting improved functionality and correctional value will insure that the prisons and security systems being designed align with operational needs and reduce the likelihood of subsequent costly future field modifications or changes.

Expand commissioning efforts. During the proposal/selection stage of the CM/GC, include all requirements for systems commissioning within the request for proposal from the CM/GC. Require the CM/GC to demonstrate in their proposal their commitment to systems commissioning and then contractually obligate them to support the commissioning process. Consideration should be given to place the Central Plant main equipment (pumps, hydronic piping, etc.) in a single subcontract and pre-qualify the sub-contract to ensure completion by a qualified contractor. Consideration should also be given to select an independent commissioning firm for building systems as well as security systems."

It is fair to say that the Oregon DOC staff and managers were pleased with the use of CM/GC on this project and in fact would use it on at least two more major projects undertaken during the same building program (accounting for $250 million more in public spending). If the report can be faulted, it would be for glossing over any problems that occurred on the project and being somewhat loose (if not out right deceptive) with the use of the terms "under budget" and "ahead of schedule." All projects in Oregon are technically "on budget" because ORS 294.100(2) requires that all contracts be adjusted by change order to exactly fit or exceed the amount paid to the Contractor. The facts are that the construction budget was initially adjusted to a reduced scope, then when either additional funds or savings were realized the budget was increased to meet the added scope. But, in the final analysis, the original GMP was $144 million and the final amount paid was $152 million, which included approximately $8.5 million in scope adjustments. Finally, the report failed to address any of the critical issues raised in the Secretary of State's Audit Division report on this project (see Section *0* below for details.)

Two Rivers Correctional Institution (TRCI)

The TRCI, according to the ORS 279.103 report [170] is described as follows: "The Project was built on a 280-acre site in Umatilla County. Groundbreaking occurred on April 5, 1997 with substantial completion of the institution on March 3, 2000. The Project's design is state of the art and includes such innovative security features as biometric palm-readers and centralized security control centers with a touch screen computer system capable of operating the entire facility from a single room. The Project is made up of several free-standing buildings that house administrative functions, a 96 bed minimum housing unit, regional transport facility, a medium security facility and several support structures including the on-site warehouse and radio transmission tower. Within the medium security facility, inmates are housed in one of fourteen general housing units, each unit capable of housing 96 inmates, or one of the two high custody units, capable of holding 88 additional inmates each."

The project team from the Oregon DOC decided to use a CM/GC PDS for the construction of the project, in part for the same reasons stated in the justification rationale for the SRCI as well as the "state of the art" and other aspects of the job noted above. The project had an original GMP of $120,668,503, which was adjusted by Change Order in June 1998 to $128,255,948 then adjusted downward in Change Order #6 to the final GMP amount of $125,266,646. The report lists the following project successes for the Design and Construction phases due to use of the CM/GC Process:

"Design/Engineering Phases:

- The CM/GC method allowed ODOC to capitalize on contractor's expertise during the design phase;
- early identification of GMP in the design phase allowed more effective use of total program funds;
- design was released in phases allowing a more aggressive construction schedule;
- prototype schematic design and final GMP were completed in less than three (3) months;
- following establishment of original GMP, savings were realized due to the collaborative team-approach to value engineering which reduced the square footage needed;
- savings in original design costs enabled ODOC to build a complete inmate workforce building that was reduced in scope to meet initial budget goals of the Project.

Construction Phase:

- The flexibility of CM/GC process allowed maximum use of inmate labor which directly reduced the cost of subcontracted work;
- direct savings to the Cost of Work due to use of inmate labor totaled nearly $1.5 million dollars;
- procurement methods allowed ODOC flexibility to accept or reject credits offered by bidders for use of inmate labor, thereby protecting ODOC from claims for unavailability of ODOC provided labor; risks for subcontractor performance remained with the subcontractor; only minor problems were encountered with use of inmate labor;
- direct purchases from local suppliers accounted for over $1.9 million dollars, and together with regional subcontracted purchases exceeded $40 million dollars;
- completion of various Project buildings was accomplished ahead of schedule including early occupancy of the minimum custody building 14 months ahead of schedule;
- early completion of Project warehouse provided cost-savings by avoidance of ODOC's rental of off-site storage space,
- overall Project was completed one month early of the originally planned completion date;
- site safety was extremely successful due to an aggressive safety program established by the CM/GC—Project realized over 650,000 man-hours and 400 consecutive days without a reportable loss-time injury;
- CM/GC returned $668,000 to ODOC as result of savings in a Contractor Controlled Insurance Program (CCIP)."

In short the benefits that accrued due to CM/GC on this project accrued through the flexibility afforded the project in the CM/GC PDS. Flexibility that allowed better use of inmate labor, a Contractor Controlled Insurance Program, and fast-tracking of the job. The report does admit that competitively bidding the work may have resulted in "marginally lower direct prices" but would have required "greater effort during design," reduced or eliminated fast-tracking of the job and increased "the need for Change Orders." The "Lessons Learned" section went on to point out these additional areas for improvement:

- "The effort required for accounting of the CM/GC reimbursement were time intensive and a fixed-fee for the CM/GC management and general condition services could be negotiated, then paid on a schedule of values;
- the Project team's roles and responsibilities need to be made as clear as possible—formal partnering sessions at the start of a project can help;
- an Owner-controlled contingency could be established in the GMP after reconciliation of the buyout status of the Cost of Work for Owner use to recover program reduced to meet initial budget goals;
- allowances could be established within the GMP without CM/GC fee until released by Owner when needed;

- pre-construction services fee should be competitively bid as part of the CM/GC procurement process. For this Project the CM/GC was paid $1 for pre-construction services. Other projects might leverage savings to the State through a competitive fee process."

The actual accounting summary of the project given in Appendix D of the report is a bit confusing:

Description **Guaranteed Maximum Price of Construction (GMP)**	**Budget**	**Actual**	**Balance**
Final Cost of Work	$114,155,186	$108,858,052	$5,297,134
CM/GC Fee	$3,208,336	$3,208,336	$0
Owner Contingency within the GMP	$7,903,124	$1,501,334	$6,401,790
Total GMP	**$125,266,646**	**$113,567,722**	**$11,698,924**

Table 30: Partial Summary of Project Accounting in TRCI 279.103 Report [170]

The implication of this summary is that the CM/GC actually received a higher percentage fee than originally contracted for since the Budget Final Cost of Work GMP was $114 million and the Actual was $108 million with the same CM/GC fee. This would mean an increase from 2.8% to 2.95%, a 4.73% increase in fee percentage. In fact, what the "Budget" reflects is the amount of money dedicated to these cost categories at the end of the job, and the total amount paid is found under the "Actual" column. The proper comparison appears to be between the $120,668,503 and the amount finally paid of $113,567,772, which represents a cost reduction of 5.88%, the CM/GC on the project actually reported payments of $115,280,000 on an original GMP of $120,668,503[94].

It should be noted that the CM/GC received letters of commendation and recommendation from this project as well as repeat work from the DOC. They reported no complaints from neighbors and that their project team received high marks and promotions from the company's review of their management of the job. The project was generally completed on time with only minor outstanding subcontractor claims (apparently unlike the SRCI discussed above). Finally, the CM/GC prepared the original GMP on the project when the plans and specifications were only 25% complete.

There appears to be no doubt that both the CM/GC and the DOC were pleased with the outcome of this project and their decision to use the CM/GC PDS on this job.

Coffee Creek Correctional Facility & Women's Intake Center

The Coffee Creed Correctional Institution (CCCF) & Women's Intake Center, the project is described in the ORS279.103 report [169] as follows:

[94] The CM/GC's reported figures were used in our DEA analysis.

"CCCF was constructed on a 108-acre site in Wilsonville, Oregon. Groundbreaking occurred on April 21, 2000, with substantial completion of Phase 1 portion of the facility on July 6, 2001 and Phase 2 portion of the facility on March 14, 2002. The CCCF design is state-of-the-art with such security features as a perimeter microwave alarm systems, a card access system to expedite internal movement of staff and centralized security control centers with touch screen computer systems capable of operating the entire facility from a single control room. The intake processing facility was developed to allow the processing and housing of both male and female inmates while maintaining gender separation. CCCF consisted of two phases of construction: Phase 1 – Women's Minimum Security Facility and Phase 2 – Women Medium Security Facility and Co-Gender Intake Center."

The report documents the following "project successes" and "trials" during the "Design, Engineering and Construction Phases" as follows:

"Design/Engineering Phase:

- Refinement of the 1997 prototypical design allowed for increased efficiency in layout and function.

- The resulting site plan and layout included efficiencies in fencing systems, site usage, and shaping of the landscape for visual screening.

- The design process utilized a collaborative effort with Building Codes Division (BCD) to apply and implement accepted alternatives and maximize to the fullest degree possible the cost-savings potential inherent in the State Building Codes.

- The design process fostered over $20,000,000 in cost saving initiatives.

- Design Team Workshops, collaboratively consolidating the perspectives of Architect/Engineer, CM/GC, Project Management Consultant, and Owner were scheduled regularly and were central to achieving Project success.

Construction Phase:

- Phase 1 of the Project was completed nearly three (3) months ahead of schedule. The support buildings (Warehouse and Physical Plant) made use of existing on-site structures and were completed six (6) months ahead of schedule. The Gatehouse was completed two (2) months early and the remaining parts of the Project were completed three (3) weeks early. Cooperation with BCD and City of Wilsonville throughout the Project and the coordination of ODOC, A/E, CM/GC and Project

Management Consultant during design and construction contributed to the early completion dates.

- Contractors from the Northwest region performed 96% of the work. Contractors from outside the Northwest performed 4% of the work. Oregon and local contractors performed 78% of the work.

- Site safety was outstanding with only one lost time accident, a tendon cut in a worker's little finger, in nearly 750,000 manhours worked. The Project received an award from Oregon OSHA for these excellent safety results.

- The use of Inside Oregon Enterprises, the inmate industries program for ODOC, for detention hollow metal products, detention plumbing fixtures, and detention furnishings resulted in nearly $4 million of work for State of Oregon inmates.

- The Project was awarded Portland General Electric's "Earth Advantage Certification" for its innovative approaches to energy efficiency measures. The CCCF Project was the first public improvement project to receive this award.

- Reconfiguration of the site plan allowed for more compact site development and reduction in length of security perimeter.

- By designing stormwater to be sheet run-off to site swales, construction and maintenance costs were reduced by eliminating area drain manholes, sediment basins, buried stormwater piping, and outflows.

- Utilizing on-site soils for perimeter landscape berms saved export costs and reduced the amount of plant material and irrigation investment while satisfying the screening and buffering requirements.

- To create a foundation pad, the site cut-and-fill design was over-excavated to the depth of foundations and utilities. Then the over-excavated portion was replaced with compacted fill within which controlled trenching could take place in a homogeneous crushed rock matrix. This built-up pad also replicated the foundation pad conditions in the filled (built-up) areas of the foundation for optimum structural continuity.

- Having the operable skylights double as potential gas canister dumps allowed for lowering of the entire roof plane which saved on the cost of wall heights, building finishes, and diminished the heated and cooled volume of the building.

- With dayroom skylights included, day lighting is provided in areas away from the window wall.

- By using a radial feed power medium voltage concept instead of the original loop feed concept, the Project saved hundreds of feet of medium voltage cable, conduit, and switching. The new design reduced the number of power substations from six (6) to three (3) substations which reduces both initial costs as well as life cycle costs due to increased ease of maintenance.

- The interior dayroom illumination was designed to incorporate 'uplight' and 'downlight' for low brightness and contrast – light bounces off the ceiling giving the entire volume of the dayroom a more even brightness. Utilizing daylight sensors and dimming ballast with the skylights reduces artificial illumination during the day. Using this same fixture in the corridors for the housing units, results in a substantial energy saving and related costs."

As in the earlier SRCI and TRCI projects some of these "successes" can be attributed to the flexibility afforded by the CM/GC PDS, however others noted above appear to be normal design and engineering issues. Engineers fundamentally exist solely to save their clients money on building materials through design, while protecting the public by implementing sound design solutions. In absence of engineers, all buildings would be one or two story buildings of less than 2,000 square-feet floor area95. It certainly should not be necessary to involve a CM/GC PDS in order for the design engineer to decide on the type of storm water that is most cost efficient. The same comment is true for the "Lessons Learned" regarding "Landscaping" design, engineered excavations and fills, including operable skylights, energy efficiency measures, and site plan layout. The fact that "Contractors from the Northwest region performed 96% of the work" and that "Oregon and local Contractors performed 78% of the work" is neither important nor a product of the CM/GC PDS unless the CM/GC discriminated against "out-of-region subcontractor's" which would probably be illegal. The project is located in the mid-Willamette valley of Oregon, south of Oregon's major city, Portland, and north of its state capitol, Salem, in the city of Wilsonville. It would seem highly unlikely that any project located in Oregon's most heavily populated corridor, would not have had these results regardless of PDS employed.

The report notes that on September 29th 1997 the CM/GC established an original GMP of $110,000.000 and the final amount paid to the CM/GC was just over $92,242,000, an approximately 16% savings[96]. The report credits the savings to the use of the CM/GC PDS in justification of the statutory requirement that the use of CM/GC "will result in substantial cost-savings to the public contracting agency." They further concluded that:

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[95] The State of Oregon allows building less than 2,000 square feet to be designed by non-engineers and non-architects. The final design still must meet the most current requirements of the applicable Building Code, however.

[96] The report states that "the final reconciled GMP of $100,000,000 was established in Amendment No. 3dated April 18, 2000.

"While the original scope was reduced to fit within the targeted GMP, efficient value optimization efforts by the Project Team resulted in all such reductions being reinstated."

And again herein lies a question about the accuracy and value of the GMP figures reported in [169]: how much of the savings from the original $110 million GMP was scope reduction? The report states that the GMP was reduced to $100 million in Amendment #3, after the scope was better defined. So, what should the comparison budget performance actually be based on? For example, could they have decided to cut the project in half to say a $55 million project then claim 50% cost reduction due to their management skills and the use of the CM/GC PDS? This issue is not addressed, but it seems clear that reporting the 16% and $17 million figures are probably disingenuous if not a deception. Probably at most the CM/GC PDS could be credited with the reduction of $7 million in costs from the revised $100 million GMP to the final payment, and that would be no small accomplishment itself. Most public projects in Oregon are smaller than $7 million in total cost to begin with! Also, it is important to note that from 1997 to 2000, the time between the original and reconciled GMP's the project location was a hot political debate in Oregon and it is not known whether the original GMP was for the original location: a former state mental hospital campus; the second site: some industrial land in Wilsonville; or, the final "actual" building site? This is not addressed in the report. Although neither is the benefit the state received from having a CM/GC on board during the site controversy and evaluation process. Something it certainly would not have been able to do if the state had relied on DBB as their PDS for the project.

Oregon State Library (OSL)

The Department of Administrative Services (DAS) published their ORS279.103 "Post Project Evaluation" report [90] on December 7th, 2001 following the OSL job. The report consists of the following:

1. "Project background giving a brief description of the project.
2. Financial information consisting of cost estimates, the Guaranteed Maximum Price (GMP), changes and the actual cost.
3. A narrative description of successes and failures in the design, engineering and construction of the project.
4. An objective assessment of the use of the CM/GC contracting method as compared to the Findings required by ORS 279.015.

The "single dominating constraint factor in this project's design and construction was the requirement that it remain open and occupied during the entire process, from concept to completion." And the report notes that requirement was met, to a large part because they chose to use the CM/GC PDS. The project did have an increase in cost from an initial GMP of $5,478,554 to a final cost of $5,840,537, a 6.6% increase.

As in the CCCF project, many of the project "successes" that are noted in the report, such as the "Seismic Improvements," the use of "plate steel" sheets instead of cast-in-place concrete, and "historic materials" searches were as much design issues as construction issues where the value did not accrue due to the use of the CM/GC PDS, or rather that it most likely could have accrued to the project had the designer spent more time to develop the job specifications.

This report does address one issue that had not been discussed in any detail in the DOC reports above, the competitively bid subcontracts:

> "One of the Project goals was to have 85%-90% of the scope of work be performed by subcontractors through a competitive bid process. While the actual percentage of GMP expenditures associated with subcontracted work is only 78% of the total, this does not take into consideration the fact that 13% of the GMP is CM/GC management fee, general conditions, performance bond fees and insurance. With those issues out of the equation the actual percentage of construction dollars paid to subcontractors is 91%."

The issue not discussed is the fact that if the project had used DBB all of the work would have been competitively bid, including the contractor's fee and General Conditions (another terms for on-site management) costs. The fact is that when multiple general contractors bid a job in a market with a large number of subcontractor's to choose from, there is a higher likelihood that a bidder will realize the lowest combination of all subcontract bidders and thus the lowest possible total project bid, than if there is only one (1) general contractor bidder. This effect may not be very large, but a study by the Audit Division for the Oregon Department of Transportation [135], showed that as the number of bidders on highway projects was positively correlated with a reduction in lowest bid as compared to the engineers estimate, which illustrates this principle precisely. It is questionable whether or not the results from [135] are comparable to the building sector since the proportion of "self performed work" in ODOT road construction contracts is significantly higher than in the building sector (and in particular CM/GC PDS where self performed work is normally kept to a minimum). But, it is important to point out that [135] actually shows greater than a 25% reduction in low bid compared to engineers estimate, when going from one bidder to more than five (5) bidders (from -.02% to -25.9%). Furthermore, the report shows that after all change orders, the low bidders on highway contracts remained significantly below the average bid at bid time, which indicates in general that low bidders do not systematically under bid work and then "make it up" on change orders, as some have thought. The reduction is cost is principally due to increased competition and in the CM/GC PDS, the competition at the CM/GC level is reduced to one.

COCC Cascade Hall Project Evaluation Report

In March 1999 the Central Oregon Community College (COCC) Board exempted the Cascade Hall project from the competitive bidding requirement of ORS Chapter 279 for its Cascade Hall project. In an undated two-page report with a one-page attachment described as the project cost accounting [115], COCC staff documented the project as required by ORS 279.103. Of the reports obtained for this research, this report was the least detailed and least well reasoned. The project was initially intended to be a classroom building for COCC, but mid-project the scope of the job changed to accommodate the fact that the Oregon State University had won approval to open a branch campus in central Oregon, noting that: "the OSU-Cascades Campus essentially stopped the design process mid-stream." Unlike a lot of CM/GC PDS jobs, this project was started, then delayed mid-plan for fifteen (15) months, while the parties decided what the impact of the OSU's presence in Central Oregon. In fact, the original exemption order was justified, in part on the determination that the campus building had to be delivered in an expedited manner, "to accommodate projected enrollment growth in COCC and University Center programs by fall 2000." At the time of the exemption order this was only six months away, but by the time the project actually broke ground that urgency no longer mattered.

The report does not allege, as required in the statute that the public agency will realize significant cost savings instead it concludes that it will achieve "greater cost reliability" than if it used DBB PDS. This conclusion probably made sense when the original project was intended to be six-months, but once the project was delayed, this justification became dubious. In fact, the report states that the project incurred a cost increase of "approximately $500,000 over the original" GMP, although the majority of this was scope additions, presumably due to the changed mission after OSU arrived. However surprisingly enough, the report concludes that the use of CM/GC PDS would reduce cost increases and delays, but the project that was intended to be occupied in the fall of 2000, was not occupied until July 2002 and would not be fully utilized until fall 2002, two years after it was originally planned.

The report claims that the cost impacts were mitigated in part by the fact that the CM/GC for the project used "$120,000.00 of its contingency and some material savings to cover other changes to the building thereby reducing the cost impact to the college by $120,000." But the "contingency" is just that, money that is set aside to pay for undefined or unforeseen work that is required in the project. For example if there was no time to do a complete soils analysis, the Owner and CM/GC may set aside in a "contingency account" some amount of money to cover cost of unknown conditions. However, if the costs exceed the contingency amount, the Owner still has to pay for them, and if the costs never materialize the Owner doesn't pay them. To say that the college received savings because the CM/GC used contingency funds to pay for changes saved the college money is simply not true. If the changes had not occurred, the college would have realized the total benefit of the contingency funds in the form of a cost reduction to the Contract. The fact is that the college did not receive any benefit from the CM/GC's use of contingency funds to cover change orders unless for some reason the college was going to allow the CM/GC to keep the contingency funds without earning that money.

It appears from the cost accounting that is attached to the report that the original GMP for the project was $4,996,410 and the total amount actually paid to the CM/GC after six change orders was $5,671,839 (which is about $175,000 more than the report claimed $500,000 Contract overage). These figures hardly support the report's claims of cost reliability and cost control, and in fact represent a relatively poor performance for a construction project, with cost increases exceeding 10% of the original budget. Granted, the project underwent significant scope changes due to the changing mission, but at the point that the project changed significantly, it is questionable whether or not the original exemption, based in part on the requirement to occupy a building in six months, reflected the changed reality of the project and whether COCC should have revisited the exemption issue and the selection of the CM/GC.

Other 279.103 Report Considerations and Comments

One problem with the 279.103 reports is that agencies do not have the time or money at the end of a project to adequately devote to making the proper evaluation as required by statute. The fact is that while the legislature made this a requirement, they put no penalties or incentives into the law to make sure these reports actually got done. Furthermore, the legislature exempted the Oregon University System, its member Colleges and Universities, and the Oregon Health and Science University from complying with this law. The end effect is that there are very few agencies that actually have to comply with the law, and fewer still that have the time and money to do so. Even the Port of Portland, one of Oregon's largest public agencies, in terms of total revenues and expenditures, has failed to produce even one single report in spite of the fact that the Port had used CM/GC one some of the largest building projects in recent years at the Portland International Airport97. In fact the probable reason that the Oregon DOC has done such a "stand-out" job in their three reports is the fact that they were so harshly criticized by the Secretary of State's Audit Division for, what the Auditors felt was mishandling of several million dollars in the process of using CM/GC PDS on one of their early prison projects. No matter, the fact is that the Oregon DOC and DAS have done the best job in completing and documenting their projects as required by ORS 279.103.

In an interview with the officials at the Department of Administrative Services, the agency that the statute requires reports to be submitted to, it was learned that there is no formal process for collecting the 279.103 reports, no specific person responsible for collecting them, and no specific location where they are kept. The states Architect, Mr. Bill Foster had possession of only one report, the report that he wrote for the Oregon State Library project [90].

Finally, Oregon statute ORS 294.100 states:

> **294.100 Public official expending money in excess of amount or for different purpose than provided by law unlawful; civil liability.** (1) It is unlawful for any public official to expend any moneys in excess of the amounts provided by law, or for any other or different purpose than provided by law.
>
> (2) Any public official who expends any public moneys in excess of the amounts or for any other or different purpose than authorized by law shall be civilly liable for the return of the money by suit of the district attorney of the district in which the offense is committed, or at the suit of any taxpayer of such district, if the expenditure constitutes malfeasance in office or willful or wanton neglect of duty.

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[97] These include the Terminal Expansion North, the Terminal Roadway Expansion, the Parking Garage Expansion and the new Terminal Access and Cover projects, which in total exceed $500,000,000.00.

This provision is quite onerous for public officials and is perhaps one reason the DOC reports do not explore the expenditures of their CM/GC Contractor as in depth as did the Secretary of State's Audits Division. In fact, both this law and state policy requiring that work be accomplished for the least cost would tend to make any public employee shy away from second guessing their decision to use one PDS over another. For this reason, and the fact that the public agencies have failed to comply with the intent of the statute, it seems reasonable to conclude that if the legislature actually wants these reports honestly completed, that work needs to be delegated either to the Audits Division or to an outside party.

Audit Reports

In 1999, following the inception of one of the largest state funded building programs in history, the $1 billion prison building and renovation projects, the Oregon Secretary of State Audits Division undertook an audit to determine if the money was being properly spent. The Auditor started by the auditing the Snake River Correctional Institution in far off Eastern Oregon, near the Idaho border, eventually three projects were audited: the SRCI, the TRCI and the CCCF (however the last of these three, the CCCF, had just begun at the time of the audit and little was addressed). The reason the Auditor undertook this mission was in part because the alternative form of contracting, CM/GC was still relatively new on these major projects and the state has an interest in knowing if the projects were being administered properly.

The Audit Division also audited the Change Order Management and Subcontractor Procurement practices on all three prison projects and made an abbreviated audit of the Valley Library expansion project on the Oregon State University campus. Multnomah County's Auditor also audited the performance of their Capitol Construction Process, but that work was motivated by concerns the county had about their own administrative procedures and was not concerned with the PDS used on the jobs.

Prison Construction Oversight

March 18, 1999 the Audits Division of the Oregon Secretary of State's office published their Audit of the prison building program [134] discussed in Section *0* above. In the cover letter, the Director of the Audits Division, John N. Lattimer stated:

> "This report contains the results of our audit of the Department of Corrections' prison construction program, specifically the department's oversight of the Snake River project. The expansion of the Snake River Correctional Institution is the first project completed on the department's current prison construction plan. Because this $1 billion construction program is the largest prison construction program in state history, the Oregon Audits Division has been reviewing this program through a series of audits. This audit of the department's construction oversight is the fourth such review. It is our intention that, by reviewing the department's construction program as it progresses, we will provide the state with meaningful recommendations for improvements.

This audit found that the department can improve its oversight of contractor payments, better monitor contract requirements, and strengthen contract terms. The department has already made some changes from the experience it gained from the Snake River project, and it should continue to make necessary improvements in its management and oversight practices to benefit both current and future construction projects. The department's response to our audit has been inserted throughout the report.

In the audit report itself, the authors admonished the DOC for inappropriate expenditures and advised that the DOC "should seek the recovery of $465,000 and review an additional $3.7 million in other payments for possible collection" from the CM/GC on the job.

The report is highly critical of the DOC's management of the SRCI and expenditures on the project and concluded in its Executive Summary that:

"The Department Should Improve Its Oversight of Contractor Payments.

A critical area in which the department has opportunities for oversight improvement involves payments made to contractors. Ensuring that progress payment expenditures are reasonable and appropriate is essential to project cost control. We reviewed project expenditures incurred by the construction manager/general contractor (CM/GC), project management, and materials testing firms for the Snake River project. For all contractors reviewed, we found that the department paid for inappropriate expenditures, including the following for the CM/GC: more than $170,000 in unallowed overhead and purchasing markups, $23,000 for catered luncheons, and almost $107,000 for excessive travel and living expenses. We recommend that the department conduct a thorough review of contractor payments, and for any payments found in error, seek monetary recovery from the responsible firm. In total, we identified $465,000 in recoverable expenditures that the department should collect; $1,700,000 in expenditures which were not in compliance with contract requirements; and an additional $2,000,000 in payments that need further review by the department."

"The Department Should Improve Its Monitoring of Contract Requirements.

Each contract specifies certain requirements for deliverables and expertise that contractors are to provide the department. We found several instances in which the department did not receive all promised deliverables from its contractors. When the department does not receive reports, schedules, and other project performance documents, its ability to monitor and control the project is limited. This also constitutes a form of overpayment as the department paid for services it did not receive. The CM/GC, project management, architect, and materials testing firms all failed to provide the department with certain required documents. For example, the CM/GC contractor promised a thoroughly documented and controlled project. One of the documents the CM/GC prepares is a monthly progress report, which it provides to the department. Our review found, however, that as of September 1998, the last monthly report the department received was for April 1997. In addition to deliverables, contractors promised specific experts to the Snake River project. We found that the CM/GC and project management firms did not comply with their contractual agreements on the use of these experts. For example, the project management firm committed 25 percent of the project director's time to the Snake River project. Our review of time billed during a four-month period found that the project director spent only four hours (less than ¼ of 1 percent of his time) on the Snake River project. We recommend that the department closely monitor its construction contracts to ensure that all requirements, including promised deliverables and expertise, are fulfilled."

"The Department Should Strengthen Its Contract Terms.

Contract formulation is critical to a construction project's success because the acceptance of imprudent terms and conditions impacts both project cost and quality. To ensure that the best interests of all parties are well protected, it is important that contracts be clear and enforceable. Our review of project expenditures noted opportunities for the department to improve its contract development practices. Two specific areas for improvement include ensuring that contract fees are clearly defined and that reimbursable costs are specific and limited. For example, the department agreed to reimburse the CM/GC firm for the cost of its safety program. The contract did not specify allowable safety program costs or establish a limit for these expenditures. As part of the contractor's safety program, we found that the department paid for safety awards, which included $5,000 for items like baseball caps and jackets, and more than $10,000 in monetary awards. To preclude overcharges and increase the ease of managing project expenditures, we recommend that the department improve its definition of and establish limits for reimbursable expenses and fees."

It is clear that the Auditors felt that at its core, the problem was one of poor contract language and poor understanding of the state's obligations and policies on the part of the project team. The audit did not allege any specific illegal activities or unlawful profiteering by any of the parties involved. But the report did find some glaring excessive charges as summarized in their Figure 1, our Table 31 below.

Item Rented	Description
Fax machines	The CM/GC rented six fax machines to the department at a rate of $165 per month. We estimate that, as of January 1998, the department paid more than $14,000 for fax machine rentals. Several fax machines are available through state purchasing; the most expensive model costs $500. **Estimated Excessive Charge: $11,000**
Copier	The department paid the CM/GC $27,390 for a copier which could have been obtained through state purchasing for $11,310. **Estimated Excessive Charge: $16,080**
All-terrain vehicles	The department paid $24,913 for the rental of four all-terrain vehicles; or $6,228 per vehicle. The department could have purchased each vehicle for approximately $3,260. **Estimated Excessive Charge: $11,873**
Flatbed truck	The CM/GC rented a 1978-flatbed truck to the department for $1,620 per month over a period of six and a half months for a total cost of $10,530. According to a local heavy-equipment rental company, it is unusual for a vehicle of that age to be rented out, and in fact, any vehicle made before the year 1990 is difficult to rent. Depending on the condition of this 1978 truck, the estimated market value ranges between $3,500 and $6,500. **Estimated Excessive Charge: $4,030 – $7,030**

Table 31 Summary of Excessive Rental Charges, Figure 1 from [134]

One of the areas the Audit focused on was a $959,000.00 charge for "survey work" performed by the CM/GC and paid for by the DOC. The DOC defends the expenditure as appropriate noting that the work was actually done, however the audit points out that state policy requires all work to be bid if the total amount exceeds the statutory limit. The interesting omission is any analysis of the costs themselves. $959,000 for surveying is a lot of money to be spent on surveyors. According to a local survey firm, their 2003 rates are $110 per hour for a survey crew, which translates to 8,718 crew hours or about 4.2 crew-years in 2003 dollars (note of course that the project broke ground in September 1995 and was completed four years later, September 1999). What this means is that the CM/GC could have hired a survey crew full-time for the entire project construction period. Of course, once the buildings are laid out, the earthwork and utilities staked, there is little for a survey crew to do on, what is principally a building project. It is likely that a lot of work that was not specifically "survey" was charged as survey work. These items may include things like interior partition and anchor bolt layout, which is usually considered "carpenter" work under the union collective bargaining agreement.

Some other project costs that raised Auditor's concerns included: $16,800 for computer equipment of the DOC project manager; $23,739 in catered lunches; $107,000 in travel related expenses; $5,586 for business lunches; and, approximately $2,000,000 in subcontractor payment that were made to the CM/GC but apparently not passed on to the subcontractors.

The audit provides for "Agency Responses" to each of the findings of the Audit Division, but allows the Audit Division the last word in the audit, as evidenced in the following exchange between the Audits Division and the Agency. Of course since it is the Audits Division's Audit, they do get the last word.

> **"Subcontractor Payments.**
>
> The CM/GC contract allowed reimbursement for payments made to subcontractors. Of the 55 subcontractors who worked on the project through September 1998, we judgmentally selected payments made to 11 subcontractors, representing almost 50 percent of subcontractor payments, for review. For seven subcontractors who appeared to have finished work on the project, we found that the CM/GC billed $38,480 more than actually paid to five of them. The four remaining subcontractors were still working on the project and were owed more than $2 million. The department should enhance its review of all subcontractor payments to ensure that it paid the CM/GC no more than the amount paid to the subcontractors.
>
> ***Agency Response:***
> *There is no mention in the report that these payments relate to contractor retainage, which is held pending completion of the work. The releasing of subcontractor retainage is a decision of the CM/GC. The department only has contractual relationship with the CM/GC. The department is also relying on the contractor's certification in accordance with section K 3 of the Standard General Conditions requiring disclosure that all subcontractors and suppliers have been paid in full and no claims are outstanding on the project.*
>
> **Audits Division Comment:**
> **The department has the responsibility to ensure that it pays the CM/GC no more than the amount the CM/GC paid to the subcontractors. Relying on the CM/GC's certification that the subcontractors were paid in full is not adequate assurance."**

The Audit concludes with a set of recommendations to help the DOC avoid some of the problems identified in the Audit. Most importantly, the Auditors focused on the Contract terms and stressed that the reimbursable expenses and fees need to be better defined in the Contract. In a later compliance memo from the Audits Division, it appears that the majority of their recommendations had been adopted.

Department of Corrections, Change Order Management and Subcontractor Bidding

November 15, 1999 the Audits Division of the Oregon Secretary of State's office published their Audit of the prison building program [136] discussed in Section *0* above. In the cover letter, the Director of the Audits Division, John N. Lattimer summarized the audit finding:

> ***Contracting Practices***
> While the prison construction contracts generally complied with laws and standards, the contracts were not clear. For example, the contract did not clearly identify which changes that occur during construction would fall under the general scope and cost of the original contract and which changes would warrant construction cost adjustments.
>
> ***Change Order Management***
> The department's independent review of project change orders was insufficient to ensure that the state's interests were protected. The department paid additional markup for costs not explicitly allowed by the contract, and allowed substantial increases to many subcontractors. Project change orders can be substantial (e.g. one increase of 3,000 percent), making a rigorous review process essential.
>
> ***Subcontractor Bidding***
> The department's contractor did not obtain bids at one prison construction site in compliance with the contract's "sealed bidding" requirements. Further, the department has made little effort to review bids awarded by its contractor. These practices do not protect against the possibility of preferential treatment of some bidders.

This audit reviewed subcontracting practices on both the SRCI and the TRCI. The report did mention the CCCF, but that project was not complete at the time of the audit. This audit generally found that both the SRCI and TRCI projects were "in compliance with ORS and OAR regulations as well as industry practices." But did go on again to criticize the Contract language, stating:

> "[w]e find that the applicable standard general conditions do not clearly identify the standards or factors under which changes warrant guaranteed maximum price adjustment. In fact, there were many SRCI changes performed within the guaranteed maximum price that fit the standard general conditions criteria. The TRCI contract provisions better satisfy the requirement to identify factors under which changes fall outside of work scope.
>
> However, the audit team found the TRCI provision to be too broad. We believe that if the CM/GC is unclear as to what is and what is not to be included in the

guaranteed maximum price, the CM/GC is more likely to include considerable contingency in its estimates."

Then went on to praise the CM/GC's for their project management, stating:

In our professional judgment, the TRCI CM/GC has exercised good oversight and review of proposed changes and subcontractor cost proposals. However, the Department should not rely solely on the contractor to protect the owner's interests in this regard. SRCI's change order records did not provide as clear evidence of change order management. However, the project management firm applied proven change management techniques to carefully track and review changes, and our review found that at times, the SRCI CM/GC reduced subcontractors' prices.

While generally chastising the DOC for relying too heavily on the CM/GC to guard the Owner's interests and questioned the large amount of change orders in the two projects, as follows:

"To date, the percentage of change order amounts has not exceeded allowable amounts. However, with allowable amounts (set by Oregon law) ranging as high as 20 percent, SRCI changes equaled 20 percent of the original guaranteed maximum price contract, and TRCI changes stand at 14 percent of the original guaranteed maximum price (at approximately 73 percent project completion)."

"Many individual subcontracts experienced increases well over 20 percent of their original value. On SRCI alone, twenty-seven subcontractors had their contracts amended by more than 20 percent, including the major subcontractors for electrical, mechanical, concrete, and site utilities. In one case at SRCI, a subcontractor had an original scope of $22,920 increase by over 3000 percent (to $525,148) through change orders."

But, the last example given by the Auditor really requires more in-depth analysis, because it is simply not plausible that "work" would be increased 3000% as noted. More likely is the possibility that this particular subcontractor took over some other subcontractor's responsibilities or scope of work. If that is the case, then there would be a similar reduction found in another subcontractor's Contract amount to offset the increase.

The Audit did evaluate the Change Orders by type or Cause and presented the following figures:

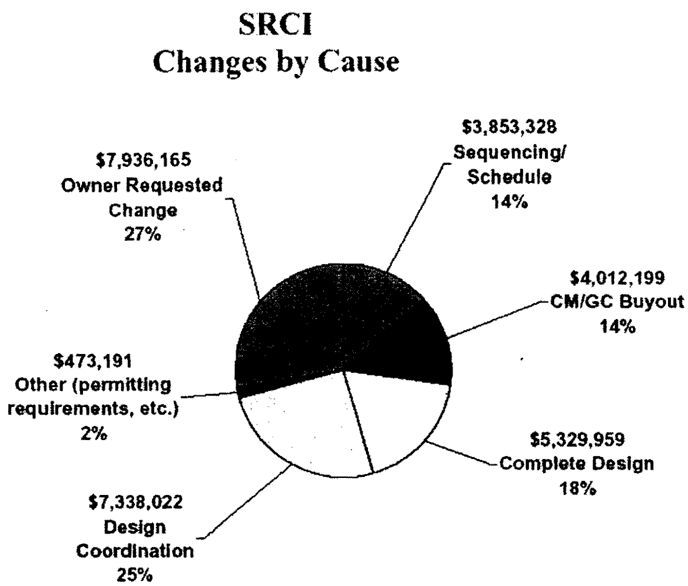

Figure 47: Change Orders by Cause from [136]

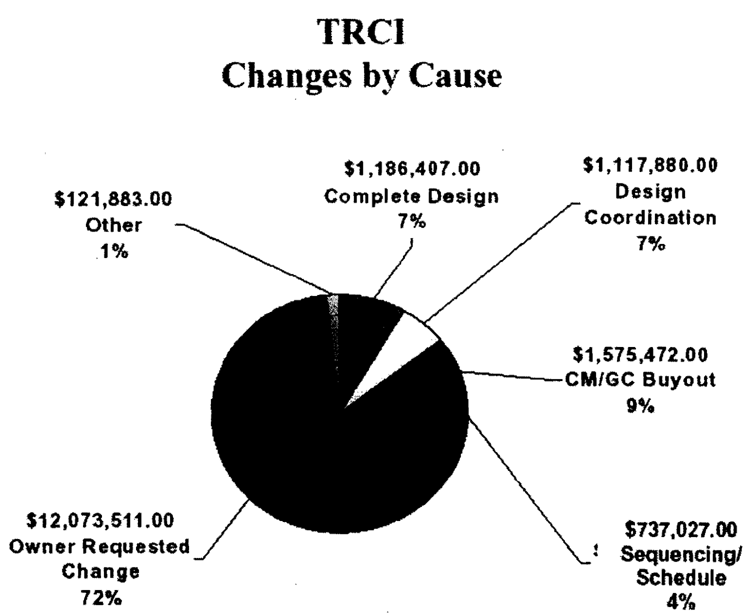

Figure 48: Change Orders by Cause from [136]

The Audit concluded with the following statements about CM/GC PDS and the DOC:

The department is embarking upon an ambitious new prison construction program. The audit team specifically invested time at the beginning of the audit to meet with department management in order to understand the program, as well as the issues and trends impacting it. Resultant findings and recommendations were intended to answer specific audit questions, and, as possible, assist the department in successfully meeting its construction program objectives.

However, the tenor of the department's reaction to the audit, as illustrated in their response, indicates a high level of frustration with the audit – which concerns the audit team. The audit team concludes that a major theme underlying this frustration, according to the number of the department's response comments related to it, is the CM/GC project management approach.

CM/GC is a newer project management approach that has not had widespread application in many sectors of the construction industry. Because of this, it provides wide latitude for defining its parameters and its application to prison construction within Oregon law. The audit team believes that, in some cases, the department has used the undefined nature of the approach to its advantage when defending management decisions and project performance. Some key occurrences in the department response included:

- The department maintains that change order management best practices differ radically between contract delivery methods, and therefore the CM/GC approach cannot be compared to other approaches, such as the more traditional "hard bid. However, change order management incorporates scope definition and control, project cost and schedule controls, and quality construction documents – factors that affect all approaches, including hard-bid contracts. If the department does not exercise good change order management practices, as outlined in audit recommendations, the result will be increased costs, schedule and cost impacts, and diminished return. The view that change order management best practices do not apply to department projects explains why the department's response views the addition of the Workforce Addition, the Laundry Transfer Building, the Regional Transport Building, the Vehicle Maintenance Building, and the Industrial Laundry as adjustments and not scope increases.
- In response to any findings or recommendations that the department increase its oversight of the subcontractor bidding process, the department response maintained that it was the role and responsibility of the CM/GC to manage lower tier relationships. This is defended based upon "minimizing project overhead and overlap of contractual responsibilities". The audit team pointed out that while it is true that the CM/GC process does give control over management of lower tier relationships to the CM/GC, it does not negate the responsibility for oversight to reduce risk to the department.

- The basis for analysis of the subcontractor bidding practices at SRCI and TRCI was a comparison against ORS 279 and industry best practices. The contract documents for both projects specify that the CM/GC support ORS 279, while the department response asserts that they are not legally bound to it since the CM/GC process falls outside of the standard public project process. However, since it is the intent of the contract documents that the CM/GC support ORS 279, the audit team determined that evaluation against ORS 279 was appropriate for benchmarking. The department should reconsider its approach in light of the contract documents taken, not the flexibility of the CM/GC approach.

It is important to note that review of the CM/GC approach was not a specific audit question the audit team was asked to answer. However, the issues it raised in light of the department's response to the audit findings and recommendations make it an issue worthy of consideration. It is the opinion of the audit team that while the department may be able to have good flexibility and fast-track ability with the CM/GC approach, the newness of CM/GC as a project management approach that is not fully defined may not necessarily be a good match with an organization establishing itself in the field of project management."

Again, in its Conclusion, the Audits Division does not criticize the PDS so much as it criticizes the DOC's management of the projects using CM/GC, in part due to the "newness" of the application and their relative lack of familiarity in using the PDS.

Department of Corrections, Prison Construction Procurement and Contract Development

On July 29, 1998the Audits Division of the Oregon Secretary of State's office published their second Audit on the prison building program [133] discussed also in Section *0* above, this audit focusing on the Procurement and Contract development systems used by the DOC. In the cover letter, the Director of the Audits Division, John N. Lattimer introduces this audit, stating:

"This report contains the results of our audit of the Department of Corrections (department). It is the second in a series of reviews of the department's prison construction program. Following a July 1998 report on infrastructure planning and development, this audit focuses on the selection methodology used by the department to procure the services of construction contractors and the department's contract development practices.

With an estimated total cost of over $1 billion, the department's prison construction program is the largest such program in Oregon history. By 2008, the department plans to increase prison capacity to accommodate an expected inmate population of more than 14,000, which is 79 percent over current population levels. At the time of our review, the department had two projects under construction with a third project planned to begin in spring of 1999.

While the department faces a significant challenge in managing a program of this size and complexity, we believe that by implementing our recommendations for contract procurement and development, the department can better protect and maximize the state's investment in prison construction."

This audit dealt with the three prisons discussed in Section 0 above, the SRCI, the TRCI and the CCCF (although again the CCCF was just underway as this audit was being performed). The audit contained three major findings and the DOC "generally agreed with the conclusions and recommendations" of the Audits Division. These were:

"Construction Contract Procurement
We found opportunities for improvement in the department's processes for contractor selection, decision documentation, and determination of contract cost. For the three construction projects referenced above, we found that selection panel composition, training, and appearance of fairness can be improved. Improvements can also be made in documenting the selection process and award decisions; we found incomplete and conflicting documentation for existing projects. Finally, we noted that the department should place more emphasis on contract price for CM/GC firms. This includes ensuring that the department has a clear understanding of cost proposals made by firms and conducting the analytical review necessary to determine if the proposed fees are reasonable. To improve construction contract procurement, **we recommend** that the department develop processes to ensure that selection panels are experienced and objective, ensure that the selection process and award decisions are fully documented, and assess whether contract cost and amounts proposed by CM/GC firms are reasonable.

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Contract Development
We found that the department can improve its establishment of cost limits and its control over contract amendments. For the Snake River-II project, we noted opportunities for the department to specify cost limits and improve the timeliness of contract amendments. For example, the department did not establish an initial total contract cost with the materials testing firm and allowed the amount paid to grow 86 percent over the original amount proposed by the firm. To improve its contract development practices, **we recommend** that the department establish contract cost limits as well as a process for improving its control over contract amendments."

This Audit focused more on the implementation of the management processes and PDS and CM/GC selection rather than the actual project, CM/GC or PDS performance. One of the early common complaints of the CM/GC process was the appearance that the selections were not "fair." This was particularly true when the first several projects were awarded to a very small select group of contractors and a large proportion of the selection criteria involved past experience in CM/GC projects, which effectively locked out may would-be competitors.

Oregon State University Review of the Valley Library Expansion Project

"During the course of other Audit work at Oregon State University," state Auditors received information regarding the settlement of a claim on the Library project totaling \$421,000 and decided to make a preliminary investigation. On December 17th, 2001, the Audits Division published their findings and recommendation from this Audit.

"As a state agency governed by state laws and rules, the university is required to document its contracting activities. The university did not adequately document its procedures in selecting either the project contractor or the architect. The state and university designed and negotiated a contract that lacked clear provisions for guiding key contracting decisions. In particular, the contract did not clearly describe which costs incurred by the contractor and subcontractors as part of the project would be considered reimbursable. Lacking clear contract language, the university, the contractor, and certain subcontractors took disputed actions that resulted in increased costs to the state.

RECOMMENDATIONS

We recommend that for construction projects the university:

- Document its selection and hiring of contractors as required by state laws and rules.
- Consider increasing the number or portion of external, independent, and knowledgeable parties serving on selection committees.

- Continue to work with the attorney general's office in creating and negotiating clear and supportable construction contracts that adequately protect the state's interests."

Here again the Audits Division focused on unclear Contract provisions and documentation but did not fault the University's use of the CM/GC PDS as the reason for the problems and cost increases incurred on the project.

Multnomah County, Capital Construction Process – Early Planning will Reduce Costs

Multnomah County Auditor, Suzanne Flynn published an Audit of four specific county building projects: the Multnomah Building, the East County Building, the Wapato Correctional Facility, and the Hillsdale Library and concluded that the county construction project management had significant weaknesses that resulted in increased costs. Specifically, the Auditor found:

- Upfront planning to define projects, establish responsibilities, identify financing options, and plan project activities did not occur in most of the projects studied. Time and resources were often committed without fully understanding what was needed, what problems might occur, or what alternatives were available. As a result, the County spent more than necessary in all four projects.
- Decision-making authority was not clear, leading to a poor understanding of roles and responsibilities. This meant that projects were often conducted in an environment of confusion and/or disagreement over control.
- The County did not have the skills and tools necessary to manage large capital construction projects. Limited administrative capacity and knowledge of project management practices led to inconsistent tracking and oversight of projects.

These deficiencies were the result of several factors, including the rapid growth in the number and size of capital construction projects. Responsibility for problems did not rest with one individual, department, or official, but weaknesses existed throughout the County. The net effect was financial loss due to major changes in scope, multiple project delays, and competing project goals. Departments and staff also did not always have the support, guidance, or training necessary to manage projects and properly do their jobs.

The Wapato Jail is the only one of these projects that was performed using the CM/GC PDS and no mention is made whether or not that had any impact on the Auditor's findings and recommendations. As in the Audits Division reports above, the County Auditor faulted the people, and county management not the PDS for these problems.

Appendix G – Oregon Public Contracting Coalition Guide to CM/GC Contracting

This appendix reviews recent reports and publications in Oregon and Washington that purport to evaluate Project Delivery Systems (PDS) and when alternate procurement methods should be used.

When the Washington state legislature allowed negotiated procurements by statute, they attached a condition that an assessment of the process had to be done after a certain amount of time had passed. Based on that report, the legislature would either allow the authorizing legislation to "sunset" or lapse, or would reauthorize it. At roughly the same time, as controversy over CM/GC procurements persisted, a group of construction professionals organized through the Associated General Contractor's (AGC) formed under the name Oregon Public Contracting Coalition and published a report assessing the proper use of CM/GC. This Section is a review of those reports.

Oregon Public Contracting Coalition Guide to CM/GC Contracting

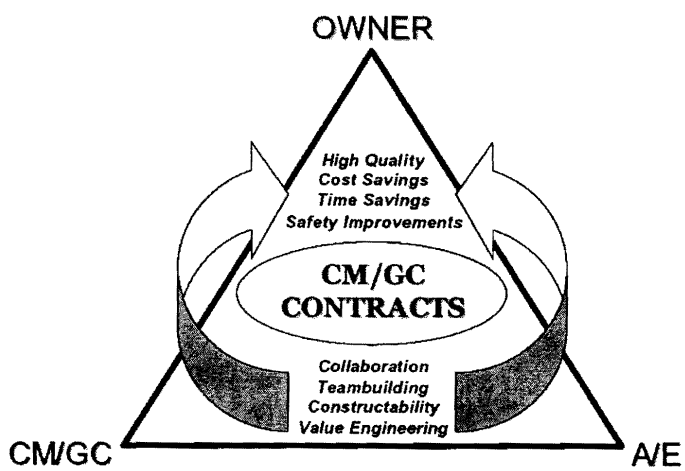

Figure 49: Cover Figure on Oregon Public Contracting Coalition Report

In February 2002 a group of construction industry professionals, several of whom served on our Expert Panel, with the aid of students and faculty from the Construction Engineering Management Program at Oregon State University, published a CM/GC Contracting Guide. This publication explains in simple and straight forward terms what CM/GC is, what the benefits are and, in the opinion of the author's what types of projects and Owners should consider using CM/GC [56]. This is a truly excellent overview of both the construction industry Project Delivery Systems, and an explanation of what CM/GC is and how it can benefit the Contraction Team. The Executive Summary of this document is as follows:

> "Since the early 1980's, the Construction Manager/General Contractor (CM/GC) project delivery method has been utilized to successfully deliver construction projects in the State of Oregon. Public agencies that have traditionally employed the design-bid-build method of project delivery increasingly select CM/GC. CM/GC offers opportunities for success that are not necessarily available through traditional contracting methods. Greater use of the CM/GC contracting method has provided the construction community with insight regarding the benefits and limitations of its use along with knowledge of the best practices for implementing it on public construction projects. Drawing on the knowledge gained from past projects, the Oregon Public Contracting Coalition (PCC) has developed this guide to assist owners with the implementation of the CM/GC contracting method on construction projects in Oregon."

The report goes on to advise prospective users of this process on: Legal Requirements (under existing state of Oregon law,) Selecting CM/GC for a project (what should be considered and how to get the best results,) The Solicitation Process, and The CM/GC Contract, The Guaranteed Maximum Price. The Executive Summary section honestly concludes with the following cautionary statement:

> "No set formula or framework exists which prescribes how the CM/GC contracting method is to be implemented. A public agency can modify the general process to suit its particular capabilities and needs. However, agencies should be cautioned that developing new practices that are too far removed from common practice may attract additional audit scrutiny. This document addresses significant practices and issues that are important to the process and should be considered by public agencies when employing the CM/GC process. It is recommended that legal counsel be sought as well to help provide guidance throughout the process. The Oregon PCC along with other industry organizations can also provide additional information and guidance."

The report expends considerable effort to define the roles and relationships of the different partners in the CM/GC process, along with their second tier partners as demonstrated in Figure 50:

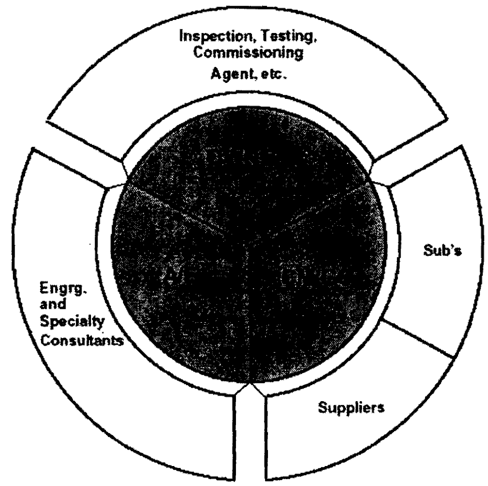

Figure 1. CM/GC Contracting Method

Figure 50: Oregon PCC Report Figure #1

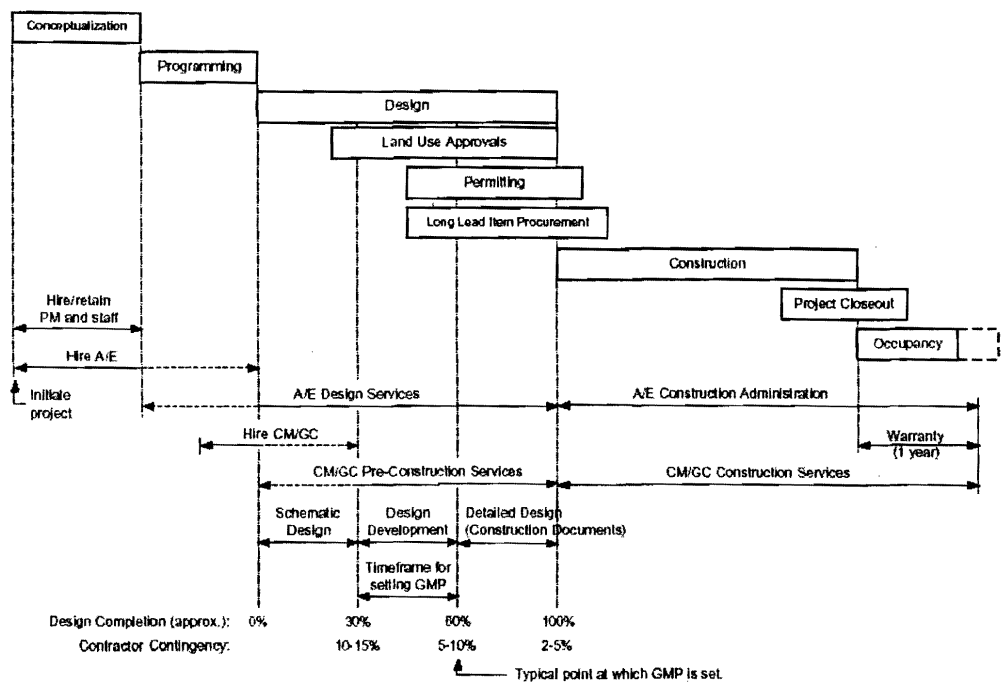

Figure 2. The CM/GC Project Timeline

Figure 51: Oregon PCC Report, Figure #2

And, recommending a time frame for engaging the CM/GC to capture maximum benefit.

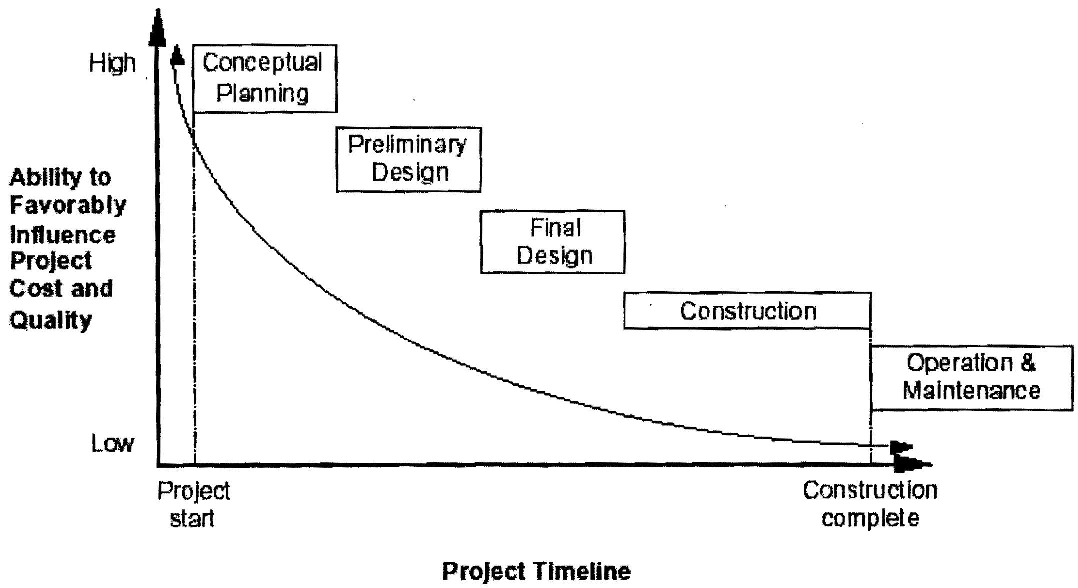

Figure 52: Oregon PCC Report, Figure #3

Figure 52 is used in the Oregon PCC Report to help visualize the impact a CM/GC can have on a project during the different stages of the project timeline. The stages depicted above do not exactly conform to those generally recommended by Architects in our Expert Panel (which included also: Conceptual and Schematic Design) but is helpful in understanding the different phases of a project and the impact a CM/GC can have on the outcome. This figure or those strikingly similar have been used in numerous presentations including one by Oregon PCC member and Expert Panel Member Bart Eberwein [85].

In answering the question: who should use a CM/GC the PCC authors respond in the following cautionary fashion that is consistent throughout the report:

> "Use of CM/GC is not restricted to any particular type of public agency. The method can be employed by all public agencies. **However, gaining approval for exemption from competitive bidding requirements, and thus the use of CM/GC, does not necessarily suggest that a public agency *should* use CM/GC for a project.** The public agency should consider other factors, especially its own capabilities and resources and the requirements that CM/GC places on the owner, when weighing whether to use CM/GC for a project. The consideration of owner capabilities is reflected in ORS 279.011(5)(d), which states that the findings must include information regarding the "specialized expertise required" for the project. The findings need to show that the agency has the capacity, through staff or contract, to bring the needed owner's representative resources to the project."

The report points out that the types of project most likely to benefit from CM/GC include those with "Technical Complexity" where the CM/GC can help to "incorporate the technical knowledge of a construction contracting firm into the development of the project's design." And "The use of CM/GC may be justified when the public agency finds that the project presents significant technical complexities which are best addressed by a team approach, with the CM/GC firm helping the public agency and designer solve specific project challenges." The report goes on to list these issues as follows:

- Operations (e.g., keeping the facility functioning during construction).
- Tenant occupancy (e.g., maintaining tenant safety and efficiency throughout construction).
- Public safety (e.g., developing a comprehensive project safety plan early in the project in concert with the owner and architect).
- Delivery of an early budget and/or GMP. This enables the public agency to provide the public, taxpayers, and other stakeholders with greater cost reliability and more effective management of the budget process.
- Fundraising (e.g., the contractor's involvement facilitates in-kind giving).
- Historic preservation (e.g., seismic upgrades while maintaining historic facades).
- Difficult remodel projects with many unknown factors.
- Projects requiring complex phasing or highly coordinated scheduling.

This report provides an excellent point of departure for any discussion on the issue of CM/GC and DBB PDS, because it provides a thorough but concise explanation of the different PDS's and an evaluation of their appropriate uses. The Oregon PCC's members include Contractor's, Consultants and Owners, but are admittedly dominated by those who support the use of alternative PDS's, specifically CM/GC in Oregon and elsewhere. In spite of that bias, the Report is remarkably evenhanded and is really intended more as a "How-to" guide than a justification or promotional publication. From conversations with Expert Panel members who also serve on the Oregon PCC, this Report was intended as a guide to public Owners on how to best decide on a PDS and how to get the most out of that decision.

Table 32 below is copied from the Oregon PCC report [56], and provides a comparison of the different PDS's with respect to different project characteristics as well as other considerations.

Criteria	CM/GC (Alternative)	Design-Bid-Build (Traditional)	Design-Build (Alternative)
Project Characteristics			
Complexity	Probably high; may have multiple bid packages.	Moderate to low.	May be driving factor; usually either high or low, but not in-between.
Schedule	Aggressive; fast-tracking possible.	Reasonable; not a key factor.	Aggressive; fast-tracking possible.
Budget	High priority; likely fixed; usually GMP.	Normal importance	Likely fixed
Program resolution	Not a driving factor.	Well resolved	Not a driving factor
Design quality	Complexity may drive higher quality.	Not a driving factor	Not a driving factor
Construction quality	Complexity implies higher quality.	Not a driving factor	Not a driving factor
Contractual Structure			
Compensation	Standard fees to design team; GMP to CM/GC.	Lump sum – all participants	Lump sum to consolidated team.
Contract arrangement	AIA contract form or variant for design; bid or negotiate for construction.	Agency – Design professional Agency – Contractor	Single-point contract with Design-Builder.
Delivery Team Structure			
Disciplines required	Standard design team plus CM/GC.	Typical project design and construction teams.	Contracting and design consolidated.
Experience needed	Complex project - high degree of experience required for all participants.	Moderate	Experience in design-build needed.
Communications	Design professional as agent; CM is contractor; "open book"	Traditional design professional as agent.	Consolidated
Legal/Risk Management			
Liability	CM/GC "at risk", but design team further exposed.	Standard	Single point of response with design-build firm.
Dispute resolution	Standard, but in partnering atmosphere.	Standard ADR, mediation, litigation.	Standard ADR, mediation, litigation.
Conflict of interest	Potential to CM/GC – dual roles during pre-construction and construction.	None	Potential professional conflict for design team.
Project Control			
Schedule control	By CM/GC	By Contractor	Agency looks to D-B team for guidance. Distribution of responsibilities within D-B team is internal issue.
Cost control	By CM/GC with design team consultation.	Contractor/Design professional	Design-Builder
Quality control	By CM/GC with design team consultation.	Design professional/ Contractor	Design-Builder
Owner staff	Must be able to meet owner's obligations in pre-construction services and contract administration.	Standard	Depends upon degree of owner control over the design and construction.

Table 32: Oregon PCC Report PDS Comparisons Table 1 from [56]

Appendix H – Oregon Database

		Project Data and DEA Input/Outputs								Virtual DMU Weights							Slacks						
Orig ID	DEA Score	PDS	Type	Financial Budget Perf	Financial Profit Perf	Schedule Performance	Quality Workmanship	Plans % Compl at Bid	# of RFI's	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule
27	100%	CMGC	School	0.890	0.000	1.000	830.000	15%	1300.000	1.000	0.000	0.018	0.703	0.000	0.000	0.279	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	100%	CMGC	Remodel	0.890	0.560	1.000	450.000	20%	500.000	1.000	0.000	0.024	0.000	0.000	0.316	0.661	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	100%	CMGC	Corrections	0.960	1.000	0.890	0.000	25%	3960.000	0.797	0.203	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	100%	CMGC	Parking	1.000	1.000	1.000	42.000	40%	0.000	1.000	0.000	0.391	0.000	0.000	0.609	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106	100%	CMGC	Corrections	0.850	0.000	0.900	19.000	40%	1350.000	0.561	0.439	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	100%	CMGC	Remodel	0.980	0.970	1.030	65.000	50%	250.000	0.759	0.241	0.000	0.000	0.000	0.238	0.762	0.000	0.000	0.000	0.000	0.000	0.000	0.000
57	100%	CMGC	Remodel	0.900	0.000	1.000	0.000	50%	850.000	0.843	0.157	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
62	100%	CMGC	Other	1.000		0.950	80.000	50%	977.000	0.723	0.277	0.173	0.000	0.545	0.000	0.282	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	100%	CMGC	Other	1.000		0.940	250.000	50%	618.000	0.675	0.325	0.011	0.075	0.414	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000
64	100%	CMGC	Institutional	1.020		1.040	554.000	50%	432.000	0.966	0.034	0.000	0.078	0.848	0.000	0.074	0.000	0.000	0.000	0.000	0.000	0.000	0.000
91	100%	CMGC	Institutional	1.070	1.000	0.470	0.000	50%	34.000	0.892	0.108	0.000	0.000	0.810	0.190	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93	100%	CMGC	Remodel	0.990	0.900	0.630	37.000	50%	100.000	0.830	0.170	0.000	0.377	0.594	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
94	100%	CMGC	Remodel	0.980	1.000	0.980	13.000	50%	96.000	0.952	0.048	0.454	0.000	0.000	0.440	0.106	0.000	0.000	0.000	0.000	0.000	0.000	0.000
105	100%	CMGC	Corrections	0.950	1.000	1.000	0.000	50%	0.000	1.000	0.000	0.000	0.000	0.000	0.522	0.478	0.000	0.000	0.000	0.000	0.000	0.000	0.000
111	100%	CMGC	School	1.000			0.000	50%	0.000	1.000	0.000	0.000	0.502	0.000	0.000	0.498	0.000	0.000	0.000	0.000	0.000	0.000	0.000
307	100%	CMGC	School	0.930	1.080	0.910	28.000	50%	12.000	1.000	0.000	0.000	0.000	0.000	0.813	0.187	0.000	0.000	0.000	0.000	0.000	0.000	0.000
312	100%	CMGC	Remodel	0.950	1.060	0.760	370.000	50%	83.000	0.983	0.017	0.000	0.015	0.000	0.985	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
65	100%	CMGC	Institutional	1.060		1.050	250.000	75%	671.000	0.936	0.064	0.003	0.000	0.833	0.000	0.164	0.000	0.000	0.000	0.000	0.000	0.000	0.000
67	100%	CMGC	Remodel	0.820		1.000	150.000	75%	130.000	0.763	0.237	0.000	0.459	0.000	0.000	0.541	0.000	0.000	0.000	0.000	0.000	0.000	0.000
89	100%	CMGC	Remodel	1.000	1.000	1.000	50.000	75%	115.000	0.848	0.152	0.023	0.570	0.000	0.113	0.294	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151	100%	CMGC	Corrections	1.080	0.000	0.820	0.000	75%	0.000	1.000	0.000	0.000	0.013	0.987	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
338	100%	CMGC	Sports Facilities	0.940	1.060	1.000	0.000	75%	1750.000	0.955	0.045	0.000	0.000	0.000	0.173	0.827	0.000	0.000	0.000	0.000	0.000	0.000	0.000
361	100%	CMGC	School	0.910	1.080	1.060	0.000	75%	0.000	1.000	0.000	0.000	0.001	0.000	0.046	0.953	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	100%	CMGC	Remodel	1.050	1.000	1.000	430.000	80%	643.000	1.000	0.000	0.538	0.000	0.000	0.462	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	100%	CMGC	Institutional	1.000	1.000	0.670	221.000	80%	404.000	0.976	0.024	0.000	0.000	0.901	0.099	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31	100%	CMGC	Corrections	0.860	1.420	1.000	110.000	80%	315.000	0.980	0.020	0.035	0.009	0.000	0.930	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	100%	CMGC	Remodel	0.940	0.910	1.000	3.000	80%	200.000	0.190	0.810	0.969	0.000	0.000	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	100%	CMGC	Remodel	0.960	1.000	1.010	25.000	80%	50.000	0.467	0.533	0.000	0.549	0.000	0.451	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
66	100%	CMGC	Office	1.090			120.000	80%	540.000	0.977	0.023	0.074	0.021	0.905	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
263	100%	CMGC	Library	0.940	1.060	0.670	0.000	80%	1000.000	0.699	0.301	0.000	0.771	0.000	0.229	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	100%	CMGC	Remodel	0.860	0.860	1.000	30.000	90%	71.000	0.000	1.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	100%	CMGC	Other	0.990	1.000	0.950	0.000	90%	150.000	1.000	0.000	0.000	0.996	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	100%	CMGC	Corrections	1.000	0.000	1.000	190.000	95%	410.000	0.988	0.012	0.006	0.000	0.543	0.000	0.452	0.000	0.000	0.000	0.000	0.000	0.000	0.000
88	100%	CMGC	Remodel	0.880	1.000	1.000	50.000	95%	200.000	0.572	0.428	0.130	0.522	0.000	0.348	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	100%	CMGC	Remodel	0.970	0.970	1.000	105.000	98%	456.000	0.961	0.039	0.316	0.000	0.000	0.684	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	100%	CMGC	Remodel	1.000	1.000	0.910	100.000	98%	69.000	1.000	0.000	0.015	0.000	0.595	0.390	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	100%	CMGC	Remodel	1.010	1.010	1.000	50.000	98%	90.000	0.000	1.000	0.000	0.105	0.384	0.511	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	100%	CMGC	Corrections	1.040		1.000	100.000	98%	250.000	0.979	0.021	0.005	0.000	0.995	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

				Project Data and DEA Input/Outputs						Virtual DMU Weights							Slacks						
Orig ID	DEA Score	PDS	Type	Financial Budget Perf	Financial Profit Perf	Schedule Performance	Quality Workmanship	Plans % Compl at Bid	# of RFI's	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule
77	100%	CMGC	Institutional	0.990	0.000	1.000	80.000	99%	1976.000	0.000	1.000	0.382	0.000	0.618	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	100%	CMGC	School	1.050	0.800	1.170	100.000	100%	0.000	1.000	0.000	0.002	0.000	0.248	0.072	0.678	0.000	0.000	0.000	0.000	0.000	0.000	0.000
335	100%	CMGC	Library	0.890	1.100	0.950	0.000	100%	300.000	1.000	0.000	0.000	0.658	0.000	0.342	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
55	100%	CMGC	Remodel	1.000	1.000	1.000	25.000	100%	30.000	0.999	0.001	0.030	0.000	0.481	0.447	0.041	0.000	0.000	0.000	0.093	0.000	0.000	0.000
60	99%	CMGC	Corrections	1.000		1.070	53.000	99%	155.000	0.986	0.014	0.013	0.000	0.501	0.000	0.486	0.000	0.000	0.000	0.277	0.000	0.000	0.000
56	99%	CMGC	Institutional	1.030	0.000	1.000	0.000	75%	350.000	1.000	0.000	0.000	0.029	0.971	0.000	0.000	0.000	0.000	0.539	0.000	0.000	0.320	0.027
76	99%	CMGC	Remodel	0.990		0.670	400.000	75%	1000.000	0.864	0.136	0.005	0.000	0.995	0.000	0.000	0.000	0.000	0.000	0.252	0.000	0.341	0.334
313	99%	CMGC	Library	0.960	1.040	0.630	0.000	75%	156.000	1.000	0.000	0.000	0.000	0.612	0.388	0.000	0.000	0.205	0.826	1.147	0.000	0.000	0.352
136	99%	CMGC	Other	0.910	1.000	1.000	0.000	100%	161.000	0.483	0.517	0.000	0.582	0.000	0.418	0.000	0.000	0.000	0.756	0.000	0.019	0.000	0.035
328	99%	CMGC	Institutional	0.960	1.030	0.900	249.000	75%	95.000	1.000	0.000	0.000	0.000	0.615	0.385	0.000	0.000	0.549	0.409	1.149	0.000	0.000	0.080
2	98%	CMGC	School	0.890	0.870	0.990	278.000	95%	1004.000	1.000	0.000	0.004	0.000	0.235	0.093	0.668	0.000	0.000	0.000	0.056	0.000	0.000	0.000
51	98%	CMGC	Remodel	1.020	0.980	0.980	50.000	80%	75.000	0.928	0.072	0.000	0.000	0.842	0.094	0.063	0.000	0.000	0.241	0.682	0.000	0.000	0.000
59	98%	CMGC	Remodel	0.990		1.000		95%	500.000	1.000	0.000	0.000	0.000	0.468	0.000	0.532	0.000	0.000	0.043	0.117	0.000	0.000	0.000
6	96%	CMGC	School	1.000	1.000	1.000	75.000	85%	675.000	0.966	0.034	0.009	0.000	0.830	0.097	0.065	0.000	0.000	0.000	0.628	0.000	0.000	0.000
326	96%	CMGC	Remodel	0.920	1.000	0.780	148.000	75%	313.000	1.000	0.000	0.009	0.000	0.609	0.382	0.000	0.000	0.033	0.000	1.539	0.000	0.000	0.159
75	95%	CMGC	Hospital	0.970		1.000		75%	1000.000	1.000	0.000	0.000	0.011	0.000	0.000	0.989	0.000	0.000	0.406	0.000	0.038	0.019	0.000
49	95%	CMGC	Remodel	0.970	0.980	0.950	0.000	100%	150.000	0.991	0.009	0.000	0.048	0.818	0.133	0.000	0.000	0.000	0.180	0.000	0.000	0.000	0.010
38	95%	CMGC	Remodel	1.020	0.880	1.000	0.000	80%	100.000	1.000	0.000	0.000	0.000	0.952	0.048	0.000	0.000	0.000	0.759	0.067	0.000	0.000	0.019
41	95%	CMGC	Office	0.990	1.000	1.000	50.000	80%	0.000	1.000	0.000	0.019	0.000	0.351	0.047	0.583	0.000	107.773	0.000	0.491	0.000	0.000	0.000
241	93%	CMGC	School	1.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.073	0.375	0.000	0.553	0.000	65.888	0.046	0.000	0.000	0.000	0.000
9	93%	CMGC	Remodel	0.950	0.950	1.070	120.000	90%	226.000	0.987	0.013	0.001	0.000	0.000	0.055	0.944	0.000	0.000	0.000	0.310	0.073	0.000	0.000
5	93%	CMGC	School	0.890	0.800	1.000	480.000	100%	865.000	0.994	0.006	0.000	0.000	0.165	0.102	0.734	0.000	0.000	0.261	0.370	0.000	0.000	0.000
87	93%	CMGC	Sports Facilities	0.920	0.000	1.000	0.000	98%	0.000	0.989	0.011	0.000	0.000	0.462	0.000	0.538	0.000	0.000	0.233	0.446	0.000	0.220	0.000
256	93%	CMGC	School	1.030	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.082	0.388	0.000	0.529	0.000	16.179	0.042	0.000	0.000	0.000	0.000
255	92%	CMGC	School	1.000	0.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.053	0.390	0.000	0.557	0.000	42.691	0.213	0.000	0.000	0.205	0.000
70	92%	CMGC	Other	0.940		0.830	2872.000	75%	450.000	0.885	0.115	0.000	0.051	0.949	0.000	0.000	0.000	0.000	0.306	0.000	0.000	0.248	0.114
159	92%	CMGC	Parking	0.000	0.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.190	0.000	0.000	0.810	0.000	165.117	0.364	0.000	0.810	0.000	0.000
165	92%	CMGC	School	1.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.051	0.391	0.000	0.558	0.000	34.015	0.252	0.000	0.000	0.253	0.000
71	92%	CMGC	Remodel	0.900		1.000	40.000	100%	67.000	0.949	0.051	0.000	0.089	0.551	0.000	0.360	0.000	0.000	0.007	0.000	0.000	0.295	0.000
149	92%	CMGC	Corrections	0.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	79.120	0.000	0.687	0.000	0.000	0.917
423	92%	CMGC	Institutional	0.000	0.000	1.000	0.000	0%	0.000	0.986	0.014	0.000	0.000	0.469	0.000	0.531	0.000	0.000	0.277	0.137	0.000	0.281	0.000
167	92%	CMGC	School	0.980	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.055	0.383	0.000	0.561	0.000	83.930	0.161	0.000	0.000	0.136	0.000
286	91%	CMGC	School	0.980	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.054	0.384	0.000	0.561	0.000	53.741	0.185	0.000	0.000	0.165	0.000
22	91%	CMGC	Office	1.010	0.000	1.000	68.000	80%	126.000	1.000	0.000	0.012	0.026	0.962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.369	0.001
266	91%	CMGC	School	0.950	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.058	0.377	0.000	0.565	0.000	90.833	0.099	0.000	0.000	0.055	0.000
42	91%	CMGC	Remodel	0.740	1.010	0.860	75.000	100%	50.000	1.000	0.000	0.026	0.072	0.000	0.902	0.000	0.000	0.148	0.000	0.000	0.059	0.000	0.044
157	89%	CMGC	School	0.930	0.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.050	0.376	0.000	0.575	0.000	43.698	0.224	0.000	0.000	0.199	0.000
197	89%	CMGC	School	0.930	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.050	0.374	0.000	0.576	0.000	32.814	0.211	0.000	0.000	0.180	0.000

				Project Data and DEA Input/Outputs						Virtual DMU Weights							Slacks						
Orig ID	DEA Score	PDS	Type	Financial Budget Perf	Financial Profit Perf	Schedule Performance	Quality Workmanship	Plans % Compl at Bid	# of RFI's	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule
40	89%	CMGC	Remodel	1.000	1.000	1.030	25.000	90%	50.000	0.998	0.002	0.049	0.000	0.000	0.040	0.911	0.000	0.000	0.000	0.812	0.061	0.000	0.000
172	89%	CMGC	Corrections	0.940	0.000	0.000	0.000	75%	0.000	0.998	0.002	0.000	0.017	0.983	0.000	0.000	0.000	0.000	0.354	0.000	0.000	0.086	0.902
213	89%	CMGC	Institutional	1.010	0.000	0.920	0.000	100%	0.000	1.000	0.000	0.000	0.000	0.637	0.000	0.363	0.000	213.020	0.134	0.818	0.000	0.143	0.000
331	89%	CMGC	Housing	1.080	0.940	0.870	405.000	90%	1.000	1.000	0.000	0.000	0.000	0.938	0.062	0.000	0.000	7.767	0.426	0.094	0.000	0.000	0.174
1	89%	CMGC	Remodel	0.980	0.980	1.000	20.000	90%	140.000	0.963	0.037	0.008	0.000	0.830	0.096	0.066	0.000	0.000	0.000	0.737	0.000	0.000	0.000
161	89%	CMGC	School	0.960	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.058	0.390	0.000	0.551	0.000	49.226	0.130	0.000	0.000	0.113	0.000
103	88%	CMGC	Remodel	0.910	1.100	1.000	0.000	90%	60.000	0.885	0.115	0.000	0.000	0.000	0.861	0.139	0.000	0.000	0.319	0.292	0.019	0.000	0.000
424	88%	CMGC	Institutional	0.000	0.000	0.830	0.000	0%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	2.334	0.000	0.719	0.000	0.000	0.048
44	87%	CMGC	Other	1.040	1.000	1.010	25.000	90%	50.000	1.000	0.000	0.019	0.053	0.928	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.024
46	86%	CMGC	Office	1.020	1.000	0.970	40.000	90%	100.000	0.960	0.040	0.054	0.000	0.898	0.048	0.000	0.000	0.000	0.000	0.150	0.000	0.000	0.050
104	85%	CMGC	Institutional	0.970	1.000	1.000	300.000	90%	1900.000	0.984	0.016	0.031	0.000	0.000	0.146	0.823	0.000	0.000	0.000	1.166	0.002	0.000	0.000
280	85%	CMGC	School	0.950	0.000	0.620	1300.000	85%	1246.000	0.913	0.087	0.000	0.054	0.946	0.000	0.000	0.000	0.000	0.140	0.000	0.000	0.426	0.347
74	85%	CMGC	School	0.900		1.000	1200.000	90%	1250.000	0.951	0.049	0.002	0.009	0.000	0.059	0.930	0.000	0.000	0.000	0.000	0.051	0.000	0.000
53	84%	CMGC	Remodel	0.970	0.000	0.000	0.000	100%	500.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.249	0.000	0.433	0.000	0.000	0.842
195	84%	CMGC	Corrections	0.970	0.000	0.530	0.000	100%	2.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	16.329	0.000	0.058	0.000	0.000	0.309
52	84%	CMGC	Parking	0.820	0.000	0.640	150.000	100%	400.000	0.903	0.097	0.022	0.168	0.810	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.166
193	83%	CMGC	Corrections	0.790	0.000	1.000	0.000	100%	11.000	0.992	0.008	0.000	0.000	0.412	0.000	0.588	0.000	0.000	0.209	0.218	0.000	0.136	0.000
68	83%	CMGC	Other	0.910			8000.000	80%	800.000	0.845	0.155	0.000	0.090	0.910	0.000	0.000	0.000	0.000	0.441	0.000	0.000	0.381	0.905
3	83%	CMGC	Institutional	0.940	0.950	0.930	120.000	90%	500.000	0.940	0.060	0.008	0.000	0.831	0.098	0.064	0.000	0.000	0.000	0.582	0.000	0.000	0.000
290	82%	CMGC	Remodel	0.880	0.000	0.820	0.000	100%	2500.000	0.889	0.111	0.000	0.133	0.675	0.000	0.192	0.000	0.000	0.120	0.000	0.000	0.045	0.000
180	82%	CMGC	School	0.950	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	86.391	0.000	0.264	0.000	0.000	0.819
319	81%	CMGC	Sports Facilities	1.010	1.000	0.880	1361.000	60%	266.000	0.987	0.013	0.000	0.000	0.000	0.797	0.203	0.000	0.000	2.858	0.432	0.092	0.000	0.000
82	81%	CMGC	Remodel	0.890	0.000	0.690	0.000	70%	600.000	0.784	0.216	0.000	0.359	0.565	0.000	0.077	0.000	0.000	0.125	0.000	0.000	0.555	0.000
72	81%	CMGC	Other	0.930		1.000	1011.000	90%	500.000	0.969	0.031	0.000	0.034	0.000	0.000	0.966	0.000	0.000	0.249	0.000	0.015	0.072	0.000
69	81%	CMGC	Remodel	0.950		0.920	500.000	70%	370.000	0.759	0.241	0.000	0.290	0.442	0.000	0.268	0.000	0.000	0.121	0.000	0.000	0.211	0.000
32	81%	CMGC	Office	0.980	0.000	1.000	115.000	90%	270.000	0.950	0.050	0.011	0.032	0.000	0.000	0.957	0.000	0.000	0.000	0.000	0.014	0.194	0.000
310	79%	CMGC	Parking	0.870	0.000	0.510	0.000	80%	126.000	1.000	0.000	0.000	0.038	0.962	0.000	0.000	0.000	0.000	0.507	0.000	0.000	0.407	0.353
15	78%	CMGC	Office	0.940	0.940	0.930	532.000	90%	311.000	0.908	0.092	0.000	0.000	0.668	0.285	0.047	0.000	0.000	0.510	0.736	0.000	0.000	0.000
83	78%	CMGC	School	0.870	0.000	0.700	38.000	70%	746.000	0.738	0.262	0.061	0.000	0.352	0.000	0.587	0.000	0.000	0.000	0.052	0.000	0.639	0.000
39	73%	CMGC	Remodel	0.860	0.910	0.870	0.000	90%	300.000	1.000	0.000	0.000	0.000	0.618	0.382	0.000	0.000	0.533	0.724	0.212	0.000	0.000	0.005
315	73%	CMGC	Remodel	0.780	0.000	0.000	0.000	100%	154.000	0.975	0.025	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.170	0.150	0.000	0.000	0.742
81	72%	CMGC	Library	0.950	0.900	0.900	206.000	70%	1121.000	0.756	0.244	0.032	0.361	0.471	0.000	0.135	0.000	0.000	0.000	0.000	0.000	0.017	0.000
204	69%	CMGC	Corrections	0.790	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	44.306	0.000	0.564	0.000	0.000	0.687
214	68%	CMGC	Office	0.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	682.296	0.000	0.927	0.000	0.000	0.683
18	67%	CMGC	School	0.930	0.000	1.000	430.000	30%	1150.000	0.239	0.761	0.026	0.374	0.601	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.020
34	100%	DBB	Hospital	0.900	1.330	0.420	316.000	93%	150.000	0.933	0.067	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	100%	DBB	Corrections	1.000	0.950	0.920	190.000	95%	90.000	0.999	0.001	0.006	0.037	0.824	0.133	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	100%	DBB	Remodel	0.960	0.730	1.000	90.000	95%	41.000	0.994	0.006	0.056	0.000	0.436	0.003	0.505	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Orig ID	DEA Score	PDS	Type	Financial Budget Perf	Financial Profit Perf	Schedule Performance	Quality Workmanship	Plans % Compl at Bid	# of RFI's	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule
29	100%	DBB	Office	0.820	1.100	1.000	180.000	95%	480.000	0.987	0.013	0.000	0.005	0.000	0.995	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	100%	DBB	Parking	0.960	0.740	0.000	82.000	95%	38.000	1.000	0.000	0.537	0.000	0.000	0.463	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79	100%	DBB	Remodel	0.850	1.000	1.000	4.000	95%	60.000	0.212	0.788	0.599	0.000	0.000	0.401	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80	100%	DBB	Remodel	0.840	0.000	1.180	146.000	95%	169.000	0.937	0.063	0.000	0.036	0.000	0.000	0.964	0.000	0.000	0.000	0.000	0.000	0.000	0.000
85	100%	DBB	Remodel	0.830	0.000	0.970	170.000	95%	58.000	0.999	0.001	0.028	0.972	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
86	100%	DBB	School	0.930	0.000	0.830	15.000	98%	220.000	0.325	0.675	0.968	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
146	100%	DBB	School	0.420	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
189	100%	DBB	School	1.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.018	0.386	0.597	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
225	100%	DBB	Library	0.920	0.000	1.000	0.000	100%	117.000	0.998	0.002	0.000	0.082	0.918	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
327	100%	DBB	Remodel	0.930	0.000	0.900	79.000	100%	157.000	0.736	0.264	0.058	0.942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
329	100%	DBB	Institutional	0.880	0.000	0.960	114.000	100%	622.000	0.247	0.753	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
390	100%	DBB	Institutional	1.090	1.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.000	0.911	0.089	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	99%	DBB	Sports Facilities	0.970	1.020	0.900	28.000	98%	0.000	0.994	0.006	0.003	0.000	0.422	0.575	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.066
400	98%	DBB	Institutional	0.990	0.950	1.050	0.000	0%	0.000	0.999	0.001	0.000	0.000	0.287	0.270	0.443	0.000	0.000	0.395	0.068	0.000	0.000	0.000
130	98%	DBB	School	0.970	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.125	0.346	0.000	0.528	0.000	127.560	0.270	0.000	0.000	0.000	0.000
95	98%	DBB	Institutional	0.950	0.800	1.050	111.000	100%	55.000	0.995	0.005	0.000	0.000	0.167	0.097	0.736	0.000	0.000	0.210	0.417	0.000	0.000	0.000
333	97%	DBB	Library	0.930	0.000	0.870	1414.000	100%	303.000	0.990	0.010	0.000	0.329	0.671	0.000	0.000	0.000	0.000	0.219	0.000	0.000	0.000	0.088
58	97%	DBB	Parking	0.960		1.080	150.000	100%	350.000	0.999	0.001	0.014	0.000	0.441	0.000	0.545	0.000	0.000	0.000	0.025	0.000	0.008	0.000
332	96%	DBB	Remodel	0.910	0.000	0.920	0.000	100%	176.000	0.940	0.060	0.000	0.239	0.333	0.000	0.428	0.000	0.000	0.663	0.000	0.000	0.000	0.000
101	96%	DBB	Institutional	0.990	0.000	0.790	0.000	100%	0.000	1.000	0.000	0.000	0.267	0.733	0.000	0.000	0.000	2.403	0.203	0.000	0.000	0.000	0.175
258	96%	DBB	School	0.920	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.070	0.335	0.000	0.594	0.000	40.768	0.132	0.000	0.000	0.000	0.000
353	95%	DBB	Remodel	0.820	1.050	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.061	0.000	0.248	0.691	0.000	114.306	0.639	0.000	0.033	0.000	0.000
419	95%	DBB	Corrections	0.910	0.500	1.100	0.000	0%	0.000	0.988	0.012	0.000	0.055	0.333	0.021	0.591	0.000	0.000	0.388	0.000	0.000	0.000	0.000
340	95%	DBB	Remodel	0.920	0.750	1.050	0.000	0%	0.000	0.984	0.016	0.000	0.000	0.216	0.082	0.702	0.000	0.000	0.528	0.345	0.000	0.000	0.000
160	94%	DBB	School	0.950	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.100	0.353	0.000	0.547	0.000	35.811	0.173	0.000	0.000	0.000	0.000
257	94%	DBB	School	1.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.082	0.371	0.000	0.547	0.000	41.015	0.082	0.000	0.000	0.000	0.000
298	94%	DBB	School	0.940	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.101	0.350	0.000	0.549	0.000	60.502	0.183	0.000	0.000	0.000	0.000
109	94%	DBB	School	0.950	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.096	0.353	0.000	0.551	0.000	160.587	0.161	0.000	0.000	0.000	0.000
396	94%	DBB	School	0.000	0.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.101	0.347	0.000	0.552	0.000	85.411	0.187	0.000	0.000	0.000	0.000
228	93%	DBB	School	0.970	0.000	1.000	0.000	100%	94.000	0.957	0.043	0.000	0.052	0.577	0.000	0.371	0.000	0.000	0.259	0.000	0.000	0.000	0.000
171	93%	DBB	School	1.000	0.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.061	0.386	0.000	0.552	0.000	61.249	0.072	0.000	0.000	0.037	0.000
116	93%	DBB	School	0.960			0.000	100%	0.000	1.000	0.000	0.000	0.050	0.370	0.000	0.580	0.000	42.015	0.213	0.000	0.000	0.174	0.000
13	93%	DBB	Remodel	0.950	1.000	0.800		100%	0.000	0.984	0.016	0.000	0.000	0.505	0.495	0.000	0.000	0.000	0.002	0.801	0.000	0.000	0.130
97	93%	DBB	School	0.880	0.000	1.090	0.000	100%	57.000	0.989	0.011	0.000	0.000	0.483	0.000	0.517	0.000	0.000	0.179	0.230	0.000	0.000	0.000
137	93%	DBB	School	0.990	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.072	0.372	0.000	0.556	0.000	107.245	0.050	0.000	0.000	0.000	0.000
127	93%	DBB	School	1.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.058	0.388	0.000	0.554	0.000	49.248	0.140	0.000	0.000	0.119	0.000
123	92%	DBB	School	1.020			0.000	100%	0.000	1.000	0.000	0.000	0.000	0.620	0.000	0.380	0.000	64.962	0.334	0.836	0.000	0.357	0.000
288	92%	DBB	School	0.970	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.071	0.369	0.000	0.561	0.000	26.951	0.054	0.000	0.000	0.000	0.000

		Project Data and DEA Input/Outputs								Virtual DMU Weights							Slacks						
Orig ID	DEA Score	PDS	Type	Financial Budget Perf	Financial Profit Perf	Schedule Performance	Quality Workmanship	Plans % Compl at Bid	# of RFI's	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule	Plans	Qual Plans	Cost /SF	Qual out	Budget	Profit	Schedule
325	92%	DBB	School	0.910	0.950	0.960	1000.000	80%	1700.000	0.958	0.042	0.002	0.009	0.000	0.059	0.930	0.000	0.000	0.000	0.000	0.004	0.000	0.000
261	92%	DBB	School	0.990	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.055	0.386	0.000	0.559	0.000	85.314	0.182	0.000	0.000	0.164	0.000
254	92%	DBB	School	0.970	0.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.058	0.381	0.000	0.561	0.000	55.919	0.118	0.000	0.000	0.084	0.000
153	91%	DBB	School	0.960	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.060	0.378	0.000	0.562	0.000	38.503	0.065	0.000	0.000	0.017	0.000
398	91%	DBB	Institutional	0.000	0.000	1.000	0.000	0%	0.000	1.000	0.000	0.000	0.045	0.393	0.000	0.562	0.000	18.269	0.366	0.000	0.000	0.388	0.000
144	91%	DBB	School	0.990	0.000	0.000	0.000	100%	0.000	0.986	0.014	0.000	0.000	0.467	0.000	0.533	0.000	0.000	0.270	0.180	0.000	0.270	0.000
154	91%	DBB	School	0.970	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.055	0.383	0.000	0.563	0.000	36.259	0.170	0.000	0.000	0.146	0.000
128	91%	DBB	School	1.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.000	0.615	0.000	0.385	0.000	30.321	0.388	0.190	0.000	0.414	0.000
173	91%	DBB	School	0.950	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.060	0.376	0.000	0.564	0.000	56.633	0.057	0.000	0.000	0.005	0.000
199	91%	DBB	School	0.000	0.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.058	0.376	0.000	0.566	0.000	81.101	0.090	0.000	0.000	0.043	0.000
118	91%	DBB	School	0.960			0.000	100%	0.000	1.000	0.000	0.000	0.056	0.378	0.000	0.566	0.000	78.347	0.142	0.000	0.000	0.107	0.000
145	91%	DBB	School	0.930	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.070	0.360	0.000	0.569	0.000	141.037	0.069	0.000	0.000	0.000	0.000
248	91%	DBB	School	0.960	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.053	0.380	0.000	0.567	0.000	37.705	0.186	0.000	0.000	0.160	0.000
174	91%	DBB	School	0.960	0.000	1.000	0.000	100%	0.000	0.989	0.011	0.000	0.000	0.461	0.000	0.539	0.000	0.000	0.235	0.191	0.000	0.220	0.000
192	91%	DBB	School	0.950	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.054	0.378	0.000	0.568	0.000	40.211	0.164	0.000	0.000	0.133	0.000
304	90%	DBB	School	0.950	0.000	0.000	0.000	100%	0.000	0.992	0.008	0.000	0.000	0.458	0.000	0.542	0.000	0.000	0.175	0.073	0.000	0.146	0.000
99	90%	DBB	Library	0.960	0.000	0.660	442.000	95%	158.000	0.931	0.069	0.004	0.000	0.996	0.000	0.000	0.000	0.000	0.000	0.278	0.000	0.000	0.204
115	90%	DBB	School	0.950			0.000	100%	0.000	0.992	0.008	0.000	0.000	0.458	0.000	0.542	0.000	0.000	0.180	0.317	0.000	0.151	0.000
260	90%	DBB	School	0.960	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.049	0.383	0.000	0.568	0.000	66.681	0.260	0.000	0.000	0.250	0.000
267	90%	DBB	School	0.960	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.048	0.384	0.000	0.569	0.000	163.613	0.281	0.000	0.000	0.276	0.000
250	90%	DBB	School	0.970	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.045	0.386	0.000	0.569	0.000	58.203	0.334	0.000	0.000	0.340	0.000
143	90%	DBB	School	0.970	0.000	0.000	0.000	100%	0.000	0.980	0.020	0.000	0.000	0.463	0.000	0.537	0.000	0.000	0.369	0.007	0.000	0.383	0.000
305	90%	DBB	School	0.960	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.046	0.384	0.000	0.570	0.000	61.548	0.304	0.000	0.000	0.302	0.000
98	90%	DBB	School	0.950	0.000	0.770	88.000	95%	90.000	0.927	0.073	0.013	0.000	0.987	0.000	0.000	0.000	0.000	0.000	0.193	0.000	0.000	0.084
175	90%	DBB	School	0.930	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.056	0.372	0.000	0.571	0.000	34.964	0.113	0.000	0.000	0.065	0.000
112	89%	DBB	Remodel	0.920		0.970	0.000	100%	211.000	0.987	0.013	0.000	0.000	0.523	0.000	0.477	0.000	0.000	0.251	0.215	0.000	0.000	0.000
100	89%	DBB	Remodel	0.970	0.000	0.840	0.000	100%	0.000	1.000	0.000	0.000	0.239	0.761	0.000	0.000	0.000	1.299	0.128	0.000	0.000	0.000	0.060
297	89%	DBB	School	0.920	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.052	0.372	0.000	0.577	0.000	215.343	0.180	0.000	0.000	0.142	0.000
147	89%	DBB	School	0.950	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.073	0.375	0.000	0.552	0.000	34.784	0.046	0.000	0.000	0.000	0.000
295	89%	DBB	School	0.930	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.043	0.378	0.000	0.579	0.000	57.041	0.340	0.000	0.000	0.336	0.000
401	89%	DBB	School	0.000	0.000	1.000	0.000	0%	0.000	1.000	0.000	0.000	0.069	0.349	0.000	0.582	0.000	68.843	0.090	0.000	0.000	0.000	0.000
352	89%	DBB	Institutional	1.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	43.821	0.000	0.503	0.000	0.000	0.886
317	88%	DBB	Institutional	0.890	0.000	0.930	0.000	100%	108.000	0.981	0.019	0.000	0.000	0.531	0.000	0.469	0.000	0.000	0.162	0.111	0.000	0.642	0.000
78	88%	DBB	Sports Facilities	0.900	0.000	0.800	90.000	99%	270.000	0.935	0.065	0.022	0.090	0.888	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.064
318	87%	DBB	Office	0.960	0.000	0.910	0.000	100%	30.000	0.999	0.001	0.000	0.000	0.485	0.000	0.515	0.000	0.000	0.034	0.381	0.000	0.014	0.000
121	87%	DBB	School	0.990			0.000	100%	0.000	1.000	0.000	0.000	0.000	0.637	0.000	0.363	0.000	3.772	0.133	0.319	0.000	0.141	0.000
24	87%	DBB	Institutional	0.990	0.970	1.000	130.000	93%	87.000	0.980	0.020	0.000	0.000	0.838	0.096	0.066	0.000	0.000	0.048	0.727	0.000	0.000	0.000
120	87%	DBB	School	0.980			0.000	100%	0.000	1.000	0.000	0.000	0.000	0.636	0.000	0.364	0.000	40.815	0.147	0.028	0.000	0.157	0.000

		Project Data and DEA Input/Outputs								Virtual DMU Weights							Slacks						
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314	86%	DBB	School	0.950	0.000	0.900	0.000	100%	133.000	1.000	0.000	0.000	0.000	0.484	0.000	0.516	0.000	0.000	0.023	0.367	0.000	0.000	0.000
90	85%	DBB	Remodel	0.850	0.100	0.750	50.000	95%	151.000	0.942	0.058	0.016	0.080	0.903	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.066
394	85%	DBB	School	0.000	0.000	1.000	947.000	100%	155.000	0.941	0.059	0.000	0.231	0.000	0.000	0.769	0.000	0.000	0.173	0.000	0.751	0.000	0.000
386	85%	DBB	School	0.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.215	0.785	0.000	0.000	0.000	33.391	0.069	0.000	0.000	0.000	0.852
155	85%	DBB	Parking	0.000	0.000	1.000	0.000	100%	0.000	1.000	0.000	0.000	0.116	0.000	0.000	0.884	0.000	143.333	0.201	0.000	0.744	0.000	0.000
323	84%	DBB	Remodel	0.880	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.255	0.745	0.000	0.000	0.000	270.729	0.154	0.000	0.000	0.000	0.847
330	83%	DBB	School	0.910	0.000	0.670	122.000	100%	188.000	0.828	0.172	0.023	0.149	0.827	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.139
33	83%	DBB	Institutional	0.920	0.670	1.000	62.000	93%	68.000	0.958	0.042	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.052	0.422	0.041	0.105	0.000
124	83%	DBB	Remodel	0.920			0.000	100%	0.000	1.000	0.000	0.000	0.000	0.621	0.000	0.379	0.000	1.597	0.298	0.216	0.000	0.318	0.000
181	83%	DBB	Institutional	0.960	0.000	0.500	0.000	100%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	36.974	0.000	0.440	0.000	0.000	0.332
182	83%	DBB	Corrections	0.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.188	0.812	0.000	0.000	0.000	99.086	0.012	0.000	0.000	0.000	0.830
347	83%	DBB	Institutional	0.850	0.000	0.700	0.000	100%	0.000	0.941	0.059	0.000	0.112	0.888	0.000	0.000	0.000	0.000	0.157	0.000	0.000	0.000	0.128
102	82%	DBB	School	0.830	0.000	0.680	0.000	100%	300.000	0.781	0.219	0.000	0.057	0.943	0.000	0.000	0.000	0.000	0.496	0.000	0.000	0.227	0.150
226	82%	DBB	School	0.950	0.000	0.770	0.000	100%	77.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.475	0.000	0.475	0.000	0.000	0.051
185	82%	DBB	Institutional	0.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	464.075	0.000	0.603	0.000	0.000	0.816
339	82%	DBB	School	0.000	0.000	0.000	0.000	100%	0.000	1.000	0.000	0.000	0.084	0.000	0.000	0.916	0.000	78.117	0.138	0.000	0.719	0.000	0.000
114	81%	DBB	School	0.970			0.000	100%	0.000	1.000	0.000	0.000	0.000	0.242	0.000	0.758	0.000	1.989	0.206	0.149	0.000	0.117	0.000
392	80%	DBB	School	0.000	0.000	1.000	0.000	90%	80.000	1.000	0.000	0.000	0.020	0.000	0.000	0.980	0.000	0.000	0.475	0.000	0.033	0.232	0.000
371	80%	DBB	School	0.000	0.000	0.000	0.000	0%	1.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	13.192	0.000	0.456	0.000	0.000	0.802
35	79%	DBB	Library	0.950	0.860	0.000	420.000	93%	600.000	0.956	0.044	0.000	0.000	0.920	0.080	0.000	0.000	0.000	0.130	0.224	0.000	0.000	0.790
23	78%	DBB	Hospital	0.980	0.480	0.920	1200.000	92%	700.000	1.000	0.000	0.000	0.000	0.972	0.028	0.000	0.000	0.000	0.417	0.490	0.000	0.000	0.060
92	77%	DBB	Remodel	0.810	0.000	0.580	48.000	95%	60.000	0.933	0.067	0.021	0.000	0.979	0.000	0.000	0.000	0.000	0.000	0.703	0.000	0.000	0.152
320	77%	DBB	School	0.000	0.000	0.660	0.000	100%	0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	203.099	0.000	0.254	0.000	0.000	0.107
36	76%	DBB	Hospital	0.960	0.400	0.700	650.000	93%	900.000	0.959	0.041	0.000	0.000	0.961	0.039	0.000	0.000	0.000	0.110	0.050	0.000	0.000	0.160
362	67%	DBB	Remodel	0.000	0.000	0.830	0.000	100%	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	15.966	0.096	0.061	0.589	0.000	0.000