Best Practice Influence On Project Changes During The Construction Phase

by

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Dedication

This work is dedicated to my wife Geralyn and my children Samantha and Nicolas for their sacrifices during my Naval career and continuing education. Geralyn's support and encouragement have enabled me to achieve goals that might not have been possible.

Acknowledgements

Special thanks to the Construction Industry Institute for its past research into project changes and permitting the use of its project databases. Information obtained from the Construction Industry Institute provided the foundation for which this thesis was based. Also, special thanks to Dr. Richard Tucker and the seven Naval Facilities Commands that provided additional data for this thesis.

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Abstract

Best Practice Influence On Project Changes During The Construction Phase

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This thesis analyzes the influence of team building, constructability, and project change management best practices on the reduction of project changes during the construction phase. Construction Industry Institute Owner, Naval Facilities Command, and Construction Industry Institute Contractor data are separately evaluated to determine if a statistically significance relationship between best practice use and a reduction in the project change rate during construction exists. Conclusions and recommendations for the reduction of the project change rate during construction are offered.

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Chapter 1

INTRODUCTION

Naval Facilities Command (NAVFAC) construction contract administrators spend much of their time evaluating, negotiating, and executing contract construction changes. Change during construction is something that must be expected; however, many of the changes that occur can be avoided or the impacts lessened if proper actions are taken prior to beginning construction. This study analyzes both private sector Construction Industry Institute projects and public sector NAVFAC projects to determine if CII best practices result in reduced cost growth during the construction phase.

The mechanism used by this study to determine the cost growth during the construction phase is the project change rate during construction (PCRC). The intent of the PCRC is to compute the percent cost increase of construction due to changes. Considering the intent of the PCRC and available information within the CII Benchmarking and Metrics (BM&M) database, the PCRC equation below was developed.

$$PCRC = \frac{Absolute\ Cost\ of\ \ All\ Changes\ During\ Construction}{Total\ Cost\ of\ Construction}$$

As can be seen in the PCRC equation above, only the net cost of all changes during construction is considered. Since the CII BM&M database considered deductive changes as negative numbers, inclusion of deductive

changes actually reduced the total cost of changes during construction and ultimately the PCRC. Although it would have been preferred to include the absolute value of deductive changes, it is assumed that deductive changes are usually minimal when compared to additive changes.

1.1 PURPOSE AND OBJECTIVE

The goal of this research is to identify practices that will reduce the PCRC for NAVFAC and other construction projects. The research compares existing CII data and new NAVFAC data relating to best practice use and changes during the construction phase of projects. Meeting the objective of this research is built around six hypotheses:

1. NAVFAC projects experience a higher PCRC than CII Owner projects. Due to the constraints of Government (NAVFAC) acquisition regulations concerning the award of design and construction contracts, it is hypothesized that the NAVFAC experiences more changes during the construction phase.
2. The total cost of the construction phase of a project has a negligible effect on the PCRC. This analysis was performed to improve the comparison between the low cost NAVFAC projects (average cost of $2,340,933) to the high cost CII projects (average cost of $19,216,948).
3. The PCRC can be reduced with an increased use of team building.
4. The PCRC can be reduced with an increased use of constructability.

5. The PCRC can be reduced with an increased use of project change management practices.
6. An increase in the combined use of team building, constructability, and project change management will result in a reduced PCRC.

1.2 Scope

To meet the goal of this research, a comparison of qualitative and quantitative data for 54 CII Owner projects, 39 NAVFAC projects and 52 CII Contractor projects has been performed. After obtaining project data for CII and NAVFAC projects, separate analyses were performed and trend curves developed. Linear regression was performed to show if project size and best practices lead to a reduction in the PCRC. The following practices and elements were analyzed for each group of projects.

- project size
- team building
- constructability
- project change management

Once the separate analyses were completed, the results were compared and best practice effect on the PCRC was determined.

1.3 Study Outline

Chapter 2 discusses the research methodology for this study. Areas covered include the sources of data used, a summary of the characteristics of the projects used, results from the *Benchmarking and Metrics Report for 1997* (CII,

1998) and the statistical method used for determining data relationships and the statistical method (*t*-test) used to determine hypothesis validity.

Chapter 3 is the literature review chapter that summarizes *Early Warning Signs of Project Change* (Oberlender 1993), *Quantitative Impacts of Project Change* (Allen 1995) and *Project Change Management* (CII SP43-1, 1994). Each of the reviewed documents provides information directly related to project changes during the construction phase.

Chapter 4 presents the data analysis. This chapter analyzes each of the six hypotheses and independently applies the hypotheses to each set of data (CII Owner, NAVFAC, and CII Contractor). Each hypothesis analysis starts with a graphical illustration (linear regression) of the relationship between the PCRC and the best practice being considered. Following the graphical illustration, the statistical validity of the relationship is discussed using either the z-test or t-test (these tests are discussed in detail in Chapter 2). Finally, the results of the data analysis are summarized at the end of the chapter. Trends that are present but not considered statistically valid will also be covered in this chapter.

Chapter 5 provides discussion, conclusions and recommendations based on the results found in Chapter 4. Potential reasons for the results found will be discussed as conclusions and recommendations for the reduction of changes during the construction phase of a project. Conclusions and recommendations are based on the results of this study combined with those of the other studies covered in Chapter 3.

Chapter 2

RESEARCH METHODOLOGY

Analyses were performed on existing CII Owner and Contractor project data and new NAVFAC data to determine best practice influence on reducing the PCRC. The following sections describe the data and methodology used for this study.

2.1 Literature Review

CII has published several research documents addressing project change including early warning signs of change, change impacts and change management. These documents are comprehensive and provide a strong foundation for further research into project changes.

2.2 CII BM&M Database

Non-NAVFAC project change data was obtained from an existing CII Benchmarking and Metrics (BM&M) database. The BM&M database is separated into four main categories - Owners Version 1, Contractors Version 1, Owners Version 2, and Contractors Version 2. The Version 1 databases contain project data taken from CII's original BM&M questionnaire. These databases contain data from projects completed from 1991 to 1996. The Version 2 databases contain project data taken from CII's improved BM&M questionnaire. These databases contain data from projects completed from 1991 to 1997. For

this study, only the Owner Version 2 and Contractor Version 2 databases were used. Reasons for not using the Version 1 databases are listed below.

1. The Version 1 questionnaire did not contain the project change management section.
2. The Version 1 questionnaire contained slightly different questions for team building and constructability. This would not allow for an equal comparison of index scores for those best practices.

2.3 CII OWNER VERSION 2 DATA

Only 54 of the 96 projects from the Owners Version 2 BM&M database were used during the analysis. Forty-one projects that were excluded did not contain adequate data for analysis. Excluded projects were missing data such as final construction cost and construction change cost. One other excluded project was not considered representative of the CII data since its PCRC was considerably greater (PCRC = 42%) than the next closest project (PCRC = 23%).

After the identification of the 54 useable CII BM&M projects was complete, the PCRC and best practices index scores for each project were calculated. Project best practice index score calculations were based on responses to various questions contained in the CII BM&M database. Since CII had existing procedures for determining index scores, the CII procedures were used (Appendix B, CII 1997).

2.4 NAVFAC DATA

While analysis of the CII project data was being performed, questionnaires were sent to seven NAVFAC commands in February 1998. The NAVFAC

questionnaire contained the same project change and best practice questions as the CII Owners Version II questionnaire (Appendix A).

The seven NAVFAC commands sent data representing 47 projects ranging from $98,485 to $26,876,714. Of the 47 projects, 39 were considered adequate for analysis. Excluded projects were either still in progress or missing data such as final construction cost and construction change cost. The analyses performed on the CII BM&M projects were also performed on the 39 useable NAVFAC projects.

2.5 CII Contractor Version 2 Data

Since both CII Owners and NAVFAC share similar owner perspectives, analysis of best practice use from the construction contractor's perspective may provide different results. Owners consider the entire project from cradle to grave when evaluating the best practices. Construction contractors, however, have a different perspective when considering a construction project. Since construction contractors generally enter a project just prior to construction, their views on the best practices will deal only with what occurs during construction. Therefore, if more favorable results concerning best practices are experience when considering the contractors' perspective, increasing the use of best practices with the construction contractor would tend to be the most beneficial when considering PCRC reduction.

Of the 92 projects contained in the Contractor Version 2 BM&M database, only 52 were used during this analysis. Thirty-eight projects that were excluded did not contain adequate data for analysis. Excluded projects were missing data

such as final construction cost and construction change cost. The other two projects that were excluded were not considered representative of the CII Contractor data since their PCRCs were considerably greater (PCRC = 71% and 1308%) than the next closest project (PCRC = 51%). All analyses were performed in the same manner as previously described.

2.6 SUMMARY OF DATA

A variety of projects were used in each of the three groups of data. Table 2.1 describes the characteristics of each of the groups. As can be seen in Table 2.1, each of the three groups of data contained a mix of project types, type of work, remuneration methods, complexity, and cost of construction.

2.7 CII BENCHMARKING AND METRICS DATA REPORT FOR 1997

CII publishes an annual report (CII, 1998) that summarizes several analyses performed on all data received from CII companies. Included in those analyses are linear regression plots to determine the value of selected best practices by comparing cost growth to best practice use. CII's analyses are very similar to those of this research. However, the CII best practices analyses consider the cost growth over all six phases of a project and not just the construction phase.

Even though the CII approach differs slightly from those of this research, a brief review of CII's results is of value since the data used for this study is a subset of the data used for the CII report.

Table 2.1: Summary of Data

		CII Owner	NAVFAC	CII Contractor
Project Type	Industrial	30	6	43
	Infrastructure	3	6	4
	Buildings	14	24	4
	Other	0	3	1
Type of Work	Grass Roots	18	10	15
	Modernization	14	24	17
	Addition	14	5	20
Customer Satisfaction	As Expected	51	34	NA
	Not as Expect	3	5	NA
Type of Contract	Lump Sum	25	32	28
	Unit Price	2	7	1
	Cost Reimb	27	0	23
Project Complexity	Low	1	4	1
	Low Avg	5	4	3
	Avg	27	21	14
	High Avg	17	9	24
	High	4	1	10
Cost of Construction	< $1M	1	22	5
	< $5M	14	11	7
	< $10M	14	5	7
	< $20M	11	0	10
	> $20M	14	1	23

2.7.1 Definitions

The six phases of a project used in CII's analyses include the following:

- Pre-Project Planning
- Detail Design
- Demolition/Abatement
- Procurement
- Construction (the only phase analyzed in this study)
- Start-up/Commissioning

To determine the impacts of best practice use on project cost growth, CII developed a best practice index score. The index score was based on the responses to questions addressing each best practice. Best practice use index scores are calculated as outlined in Appendix B (CII, 1998).

For consistency in comparing responses from different sources, CII also defined the term "project cost growth" as the following:

$$\text{Project Cost Growth} = \frac{(\text{Actual Total Project Cost} - \text{Initial Predicted Project Cost})}{\text{Initial Predicted Project Cost}}$$

CII recognized that the definitions of the terms used in calculating the project cost growth are different depending on the perspective (owner/contractor) and situation. Definitions for the terms are listed below (CII 1998).

Actual Total Project Cost:

- Industrial Owners – TIC at turnover (excluding land cost).
- Building Sector Owners – Total cost of design and construction to prepare the facility for occupancy.
- Contractors – Total cost of the final scope of work.

Initial Predicted Cost:

- Owners – Budget at the start of detailed design.
- Contractors – Cost estimate used as the basis of contract award.

2.7.2 Team Building versus Project Cost Growth

CII found a statistically significant relationship between team building use and overall project cost growth. As shown in Figure 2.1, an increased use of team building resulted in a decrease in overall project cost growth (CII, 1998).

2.7.3 Constructability versus Project Cost Growth

CII found a statistically significant relationship between constructability use and overall project cost growth. As shown in Figure 2.2, an increased use of constructability resulted in a decrease in overall project cost growth (CII, 1998).

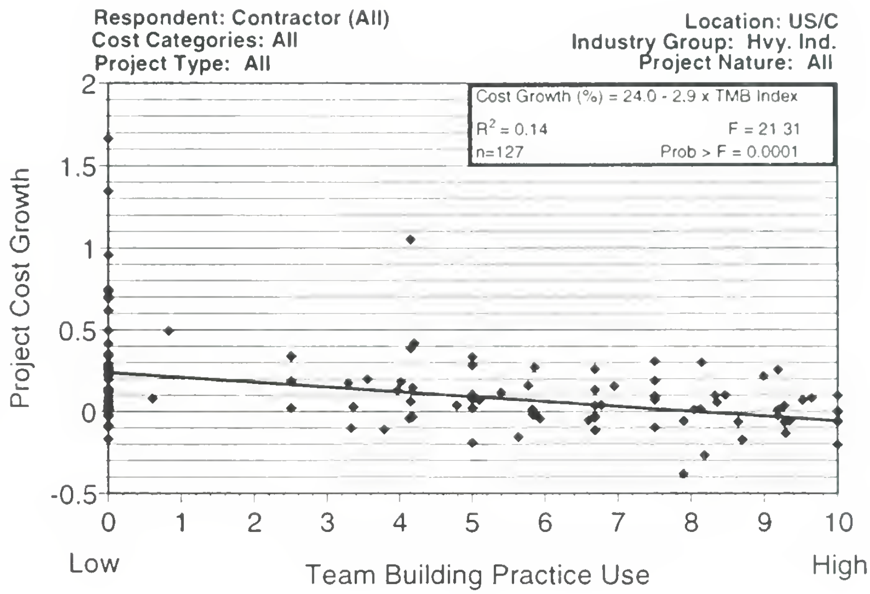

Figure 2.1: Team Building versus Project Cost Growth

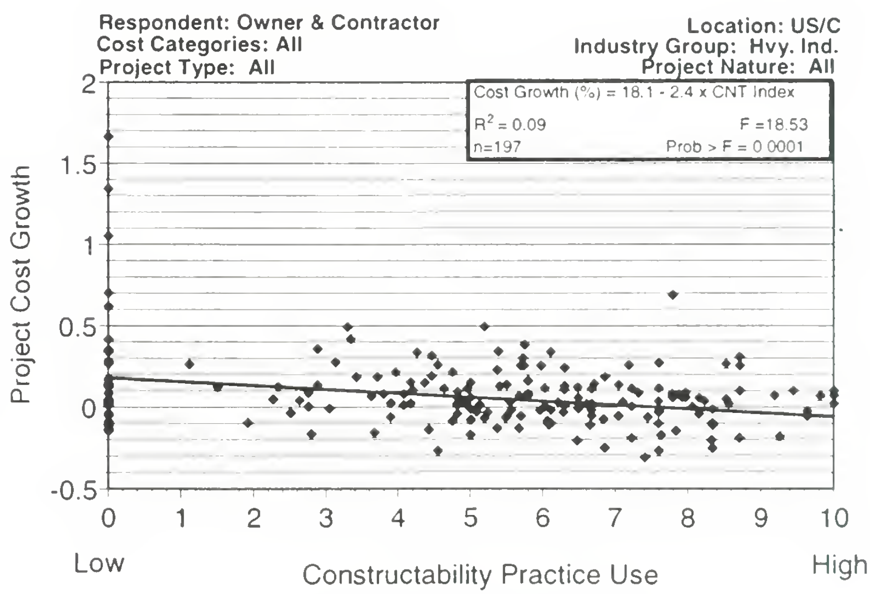

Figure 2.2: Constructability versus Project Cost Growth

2.7.4 Project Change Management versus Project Cost Growth

CII found a statistically significant relationship between project change management use and overall project cost growth. As shown in Figure 2.3 below, an increased use of project change management resulted in a decrease in overall project cost growth (CII, 1998).

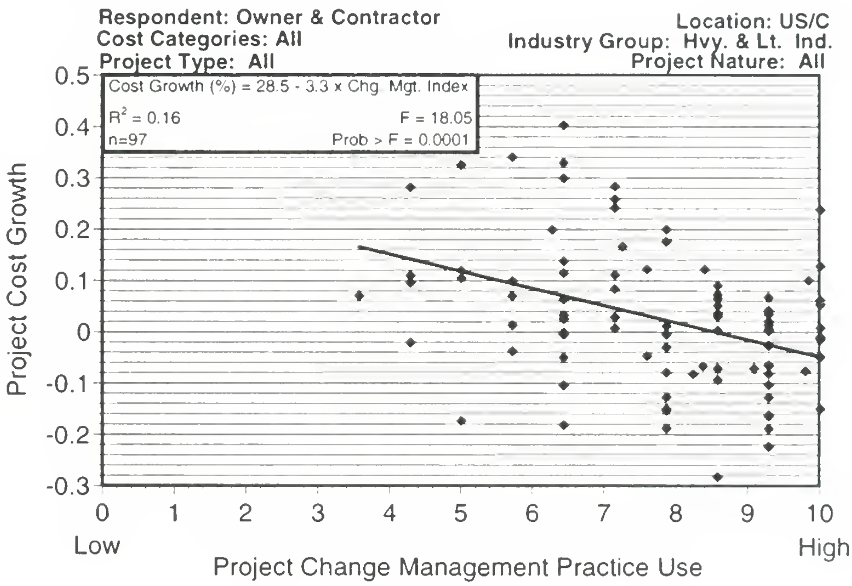

Figure 2.3: Project Change Management versus Project Cost Growth

2.7.4 Summary: CII BM&M Report 1997

The analyses performed by CII showed that an increased use of team building, constructability, and project change management resulted in a decrease in overall project cost growth. Similarly, this research will determine whether or not an increased use of team building, constructability, and project change management results in a decrease in cost growth during the construction phase.

2.8 ANALYSIS METHODOLOGY

Upon completion of calculating individual project best practices indices, linear regression trend analyses were performed to determine the statistical validity of hypotheses 2-6. The following five graphs were developed:

1. Construction Phase Cost vs. PCRC
2. Team Building Index vs. PCRC
3. Constructability Index vs. PCRC
4. Project Change Management Index vs. PCRC
5. Combined Index vs. PCRC

Linear regression with *t* distribution analysis was then performed to determine trends and statistical significance. The *t* distribution analysis compared the slope of the best fitting lines calculated using linear regression to a hypothesized slope of zero (null hypothesis, H_O). If the calculated slope is statistically considered the same as a slope of zero, "the variables X (best practice) and Y (PCRC) are independent and the fitted line is of no value" (Blank, 1980). Ultimately, the purpose of the *t* test is to determine whether to not reject or reject the null hypothesis. In the case of this study, it will be determined whether to reject that the PCRC is independent of the best practices (reject H_O), or to not reject that the PCRC is independent of the best practices. If the result is to reject H_O, it is shown that a statistically significant relationship between the PCRC and the best practice exists and the hypothesis is proven.

This study used a significance level of $\alpha = 0.05$ (95 percent confidence level). For the slopes to be considered statistically the same (not reject H_O) for

CII Owner or Contractor data the *t* test must result in a value of $|t| \leq 2.000$, and for NAVFAC data the *t* test must result in a value of $|t| \leq 2.021$. In other words, if the result of the *t* test falls within the acceptance region, the slopes are considered the same with a 95 percent confidence level and research hypothesis 1 is accepted and hypotheses 3 through 6 are rejected. Research hypotheses 3 through 6 are also rejected if the appropriate trend is not present. Conversely, if the *t* value is outside the acceptance region and the predicted trend is present, research hypothesis 2 is rejected and hypotheses 3 through 6 are accepted. Table 2.2 shows the required t values for different significance levels (Blank, 1980).

Table 2.2: The *t* Distribution

Sample	*Significance Level* (α)					
Size	*0.20*	*0.10*	*0.05*	*0.02*	*0.01*	*0.002*
40	1.303	1.684	2.021	2.423	2.704	3.307
60	1.296	1.671	2.000	2.390	2.660	3.232

For hypothesis 1, the statistically validity was tested against the null hypothesis using the *z*-test with a 95 percent confidence level. This test is similar to the *t* test since its purpose is to either reject or not reject a null hypothesis and acceptance regions apply.

In this case, for the NAVFAC data to be considered statistically the same as the CII Owner data with respect to the PCRC the z-test must have a value of $|z| \leq 1.960$. If the z value falls within the acceptance region, the PCRC of the data sets will be considered the same with 95 percent confidence and the research hypothesis is rejected. Conversely, if the value falls outside of the range and NAVFAC has a greater PCRC, research hypothesis 1 is accepted.

Chapter 3

LITERATURE REVIEW

A cursory literature review was conducted to provide NAVFAC readers a source document that introduces many areas of project change management during construction. Several CII studies will be covered in detail, but not in full. If a reader desires further information concerning a study referenced, they are encouraged to obtain the source document and read it in full.

Project change management is a topic for which much has been researched and written by CII and other sources. The literature review for this research was primarily done using previous CII research reports.

3.1 EARLY WARNING SIGNS OF PROJECT CHANGE

A study by Oberlender and Zeitoun identified some of the early warning signs of project change (Oberlender, 1993). The researchers primary objective was to "identify factors which are known prior to the commencement of construction, which are early signs of project cost and schedule growth." Oberlender and Zeitoun sent questionnaires and received data from 23 CII member companies representing 104 projects. Individual project Total Installed Cost (TIC) ranged from $5 million to $226 billion.

3.1.1 Definitions

Oberlender and Zeitoun used the following definitions for their research:

- *Change order* is "a modification to a construction contract where the resultant impact on cost and time must be mutually agreed upon by the owner and contractor."
- *Cost growth* is "the increase in construction cost, taken as a percentage of the original contract dollar amount."
- *Schedule growth* is "the increase in contract duration, taken as a percentage of the original approved contract duration."
- *Money Left on Table (MLOT)* is "the difference between the low bid and the next higher bid."
- *Percentage of MLOT* is the MLOT divided by the original low bid.

3.1.2 Data Analysis

The data was separated into cost reimbursement and fixed price categories. Oberlender and Zeitoun believed that fixed price projects generally had minimal changes and low risk, whereas cost reimbursable contracts are schedule driven projects with lesser defined scope and extensive changes. Each type of contract was analyzed independently. Trend curves showing percentage of cost and schedule growth over four 25 percent intervals during construction were developed. However, for this study only the cumulative cost and schedule growth will be reviewed. Figure 3.1 shows the contract type distribution.

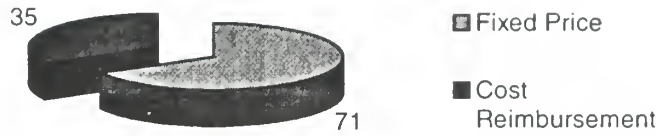

Figure 3.1: Contract Type Distribution

3.1.3 Fixed Price Projects

After analyzing the fixed price project data and considering several different factors that could indicate project change, the researchers concluded the following (see Table 3.1, Oberlender, 1993).

- A high percentage MLOT (>4%) resulted in high cost and schedule growth.
- Contracts which had a low number of bidders (< 5) had higher cost and schedule growth.
- The project execution format influenced the potential for change. Construction Management projects experienced a high cost growth, but a very low schedule growth. Design/Bid/Build projects had a high schedule growth, but low cost growth. Design/Build projects had both low cost and schedule growth.
- Using an open bid solicitation vice an approved bidders list solicitation resulted in high schedule growth.

- Government projects experience a high schedule growth and low cost growth while private projects experience a high cost growth and low schedule growth.

Table 3.1: Fixed Price Findings Summary

Factor	Cost Growth*	Schedule Growth **
Money Left On Table		
MLOT > 4%	12.1%	19.0%
MLOT <4%	3.9%***	6.0%
Number of Bidders		
Number of Bidders < 5	12.0%	21.5%
Number of Bidders > 5	4.8%***	11.5%
Execution Format		
Construction Management	12.1%	2.0%
Design/Build	4.6%	0.0%
Design/Bid/Build	2.5%	10.0%
Bid Solicitation		
Approved Bidder List	6.4%	0.0%
Open Bids	4.6%***	18.0%
Owner Type		
Private	8.1%	0.0%
Government	3.6%	17.0%

*The median cost growth for all 71 fixed price projects was 5.3%
**The median schedule growth for all 71 fixed price projects was 9.0%.
***These values did not pass the t-test with a 90% confidence level.

3.1.4 Cost Reimbursement Contracts

After analyzing the cost reimbursement project data and considering several different factors that could indicate project change, the researchers concluded the following (see Table 3.2, Oberlender, 1993):

- The primary driving factor influenced the potential for change.
- When quality is the primary driving factor, cost and schedule growth are low.
- When cost is the primary driving factor, cost and schedule growth are high.
- When schedule is the primary driving factor, cost growth is high and schedule growth is slightly increased.
- The project execution format influenced the potential for change.
- Construction Management projects had high cost and schedule growth.
- Design/build and design/bid/build projects had low cost and schedule growth.
- Projects that performed work primarily using subcontracting (versus direct hire) had high schedule growth.

3.1.5 Summary: Early Warning Signs

Oberlender and Zeitoun's findings may assist in the early identification of projects that will experience change. When properly addressed, the early identification of factors that will increase the potential for change can be of great value. NAVFAC contracting personnel can either make adjustments to the project to reduce the potential for change or plan for providing adequate

contingency funding prior to award. With funding readily available, change orders can be processed quickly, significantly reducing or eliminating the need to compensate contractors for unnecessary delay.

Table 3.2: Cost Reimbursable Findings

Factor	Cost Growth*	Schedule Growth **
Primary Driving Factor		
Quality	6.1%	4.5%
Cost	9.9%	15.0%
Schedule	10.3%	9.0%
Execution Format		
Construction Management	9.5%	13.0%
Design/Build	5.3%	4.5%
Design/Bid/Build	6.4%***	3.0%
Work Distribution		
Direct Hire	10.8%	-0.8%
Subcontract	8.0%***	13.0%

*The median cost growth for all 35 cost reimbursable projects was 6.8%.
**The median schedule growth for all 35 cost reimbursable projects was 7.5%.
***These values did not pass the t-test with a 90% confidence level.

3.2 QUANTITATIVE IMPACTS OF PROJECT CHANGE

Allen and Ibbs studied the quantitative impacts of project change in 1995 (Allen, 1995). The objective of their study was to "quantify the impact of project change during the detailed design and construction phase." For the purposes of this study, only the construction phase results will be reviewed. The researchers sent questionnaires and received data from 35 different organizations representing

104 projects. Individual project Total Installed Cost (TIC) ranged from $3.2 million to $1.2 billion with most (80.8%) of the projects falling in the $3.2 million to $100 million dollar range. Projects submitted covered a wide variety of owner, contract, and project type.

The majority of the Allen and Ibbs' research focused on three assumptions:

1. Change Implementation Efficiency: Changes that occur late in a project are implemented less efficiently than changes that occur early in the project.
2. Labor Productivity: The more change there is on a project, the more of a negative impact there is on labor productivity.
3. Hidden Cost of Project Change: Hidden costs of change increases with more project change.

The researchers performed additional analyses involving project management. Section 3.2.4 discusses some of the results from these analyses.

3.2.1 Change Implementation Efficiency

To allow for the comparison of projects in terms of late project change efficiency impact, the researchers computed a change ratio (Permanent Material/TIC) at various times during each project. If their first assumption were true, the ratio would decrease as changes were made later in the project. Although Allen and Ibbs were unable to statistically prove this, late changes during the construction phase did have a tendency to decrease the change ratio.

These results would lead one to believe that changes implemented late in the construction phase of a project are implemented less efficiently resulting in an increased TIC.

3.2.2 Labor Productivity

To allow for the comparison of projects in terms of the impact project change has on labor productivity, the researchers computed a productivity index (Earned Work Hours/Expended Work Hours). Hypothesis two proved to be statistically valid for the sample used. When analyzing construction change, the results indicated that "construction change greater than 5 percent results in negative construction productivity or productivity less than planned." Figure 3.2 below shows that an increase in construction change results in a steady decrease in the construction productivity index.

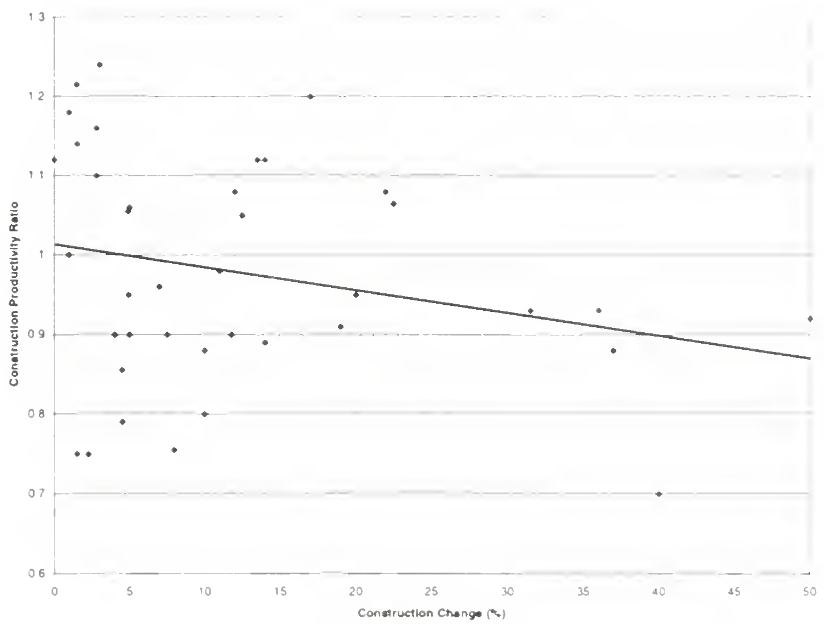

Figure 3.2: Construction Change versus Construction Productivity

3.2.3 Hidden Cost of Project Change

Allen and Ibbs recognized that the direct costs incurred due to change (labor, material, overhead, profit, etc.) are "fairly easy to identify and account for." However, quantification of the other hidden costs is more difficult to estimate. The researchers identified some hidden costs of project change to be delays, lowered productivity, poor communication and rework. Several methods for comparing the hidden cost of project change were analyzed by Ibbs and Allen. Three of the methods were shown to be statistically valid. The most statistically valid of those methods compared Total Change Ratio versus Hidden Cost/Final Cost Budget. The researchers developed the following definitions for their analysis.

- *Total Change Ratio* = Total Project Change/TIC[1]
- *Hidden Cost* = TIC – Final Control Budget – Known Final Change Value

The analysis described above showed that hidden costs increase as the total project change increases. Figure 3.3 summarizes the results (Allen, 1993).

3.2.4 Project Management Analysis

Allen and Ibbs also performed several additional analyses due to the "wealth of information contained in the database." Construction project change related analysis included the following:

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[1] The absolute value of each project change was used in determining Total Project Change to avoid reductions and additions in work canceling each other. This shows an absolute impact of both positive and negative changes.

- Project Rate of Contingency Draw-Down versus Percent Design and Construction Complete.
- Construction Change versus Schedule Overlap[2]

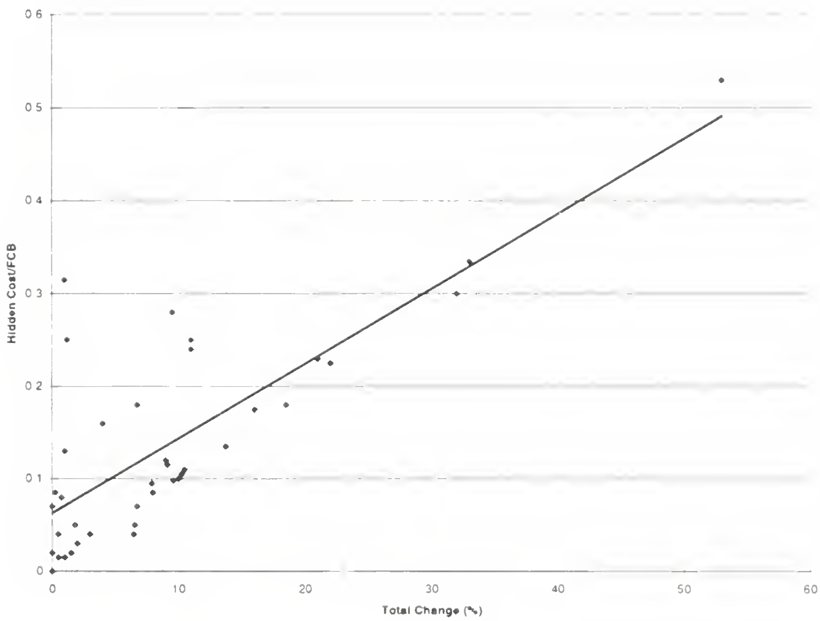

Figure 3.3: Total Change versus Hidden Cost/FCB

3.2.4.1 Contingency Draw-Down

This analysis is reviewed to illustrate the timing for the removal of contingency from construction projects. It has been the author's experience that upon award of a locally NAVFAC funded projects, remaining/contingency funds are removed and used elsewhere. This creates problems when changes are needed and funding is unavailable. Figure 3.4 illustrates the rate of contingency draw-down for the sample previously examined (Allen, 1993).

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[2] Schedule overlap is defined as "the construction percentage complete when engineering design finishes."

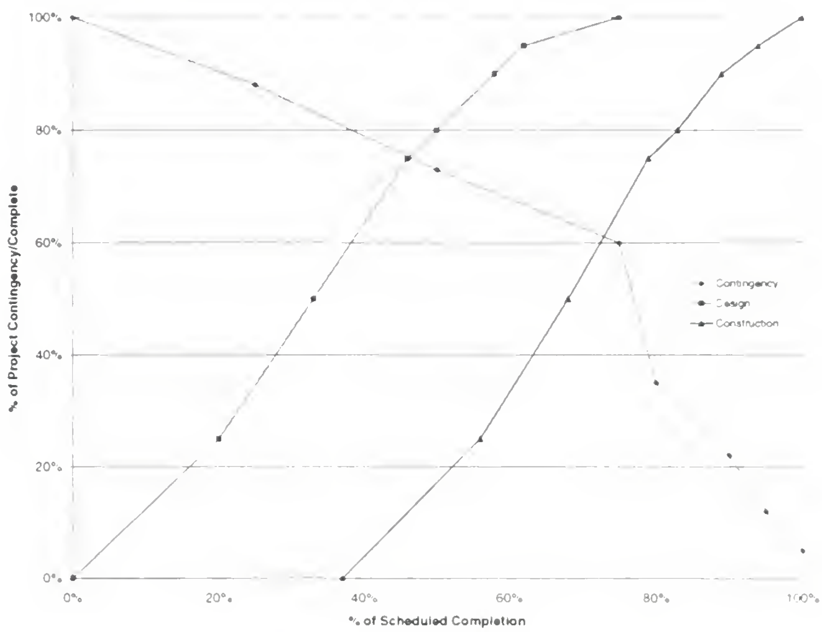


Figure 3.4: Percent of Project Contingency vs. Percent Schedule Complete

As can be seen in Figure 3.4 above, contingency funds are gradually decreased until the project is approximately 75 percent complete. This gradual decrease eliminates ensures that funding is readily available for need changes.

3.2.4.2 Schedule Overlap

Results from analyzing the amount of construction change versus the amount of schedule overlap showed an increase in change as overlap increased. This would lead one to believe that the design-bid-build format of contract execution was superior to design-build when considering construction project change. This may be valid however, it must be noted that only 11 projects were used for the analysis.

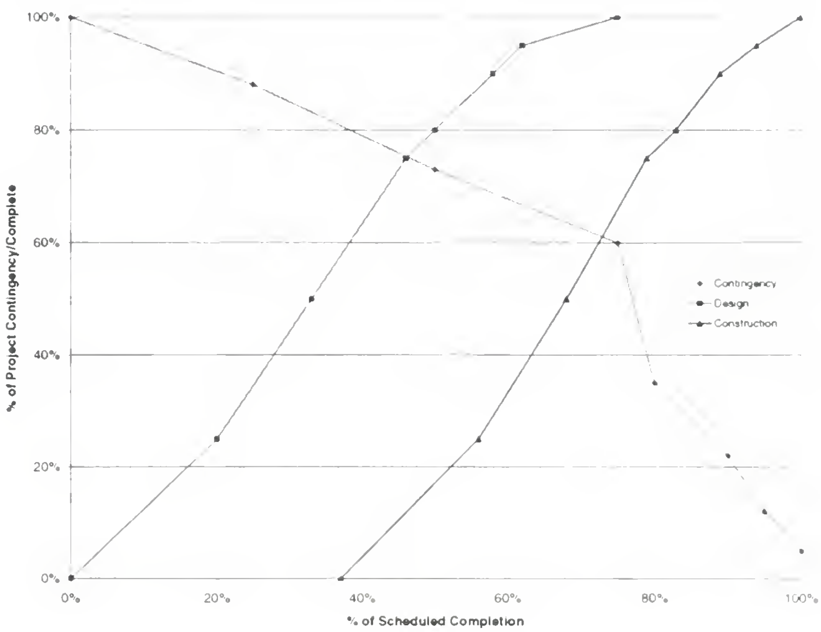


Figure 3.4: Percent of Project Contingency vs. Percent Schedule Complete

As can be seen in Figure 3.4 above, contingency funds are gradually decreased until the project is approximately 75 percent complete. This gradual decrease eliminates ensures that funding is readily available for need changes.

3.2.4.2 Schedule Overlap

Results from analyzing the amount of construction change versus the amount of schedule overlap showed an increase in change as overlap increased. This would lead one to believe that the design-bid-build format of contract execution was superior to design-build when considering construction project change. This may be valid however, it must be noted that only 11 projects were used for the analysis.

3.2.5 Summary: Quantitative Impacts

Allen and Ibbs' findings should provide contract administrators the incentive to reduce project change as much as possible. Being the cause of a negative impact on contractor productivity generally leads to inflated change order proposals. Since the standard NAVFAC form doesn't account for such impacts, it is often difficult to justify compensating the contractor for productivity loss and other hidden costs. Productivity impacts are a real financial problem to the contractor and they must be addressed in a fair and reasonable manner. If the owner causes the contractor to incur significant productivity losses and fails to compensate the contractor, the contractor will most likely file a claim against the owner. Since hidden costs are difficult to identify and quantify, the best way to handle them is to avoid them by minimizing project change.

3.3 PROJECT CHANGE MANAGEMENT

CII formed a Project Change Research Team to "find solutions to or, preferably, the means of avoid" problems encountered due to project change (CII SP43-1, 1994). The research team's publication includes a description of a typical project life cycle, dynamics of change management, identification of effective change management principles, recommended practices, and a prototype change management system. To provide a comprehensive summary of the research team's findings is not the purpose of this paper. Instead, each of the above topics will be briefly covered providing the reader with a quick insight to the publication's contents.

3.3.1 Phases of a Project

In performing its research, the team used CII's standard six phases of a typical project.

1. Business Planning
2. Project Planning
3. Project Scope Definition
4. Detailed Design
5. Construction
6. Start-up and Operation

The different phases of a project are identified to illustrate the need for an effective change management process. Due to the many agreements and numerous levels of personnel involved in each phase, a standard process is needed to ensure clear consistent communication from one phase to the next throughout the life of a project.

3.3.2 Dynamics of Change Management

Research team members concluded that an "effective change management process should allow for the complex dynamics that will likely develop, and should provide a disciplined approach for recognizing, evaluating, and implementing changes in a timely and cost-effective manner" (CII SP43-1, 1994).

They also believed that change and change management are affected by the following project elements.

- Project Scope
- Project Organization
- Work Execution Methods
- Control Methods
- Contracts and Risk Allocation

Key issues that must be addressed in each of the above project elements will not be covered here, but can be found in the team's publication.

3.3.3 Principles of Effective Change Management

Five principles of effective change management were identified.

1. Promote a balanced change culture (encourage beneficial change and prevent/discourage detrimental change).
2. Recognize change.
3. Evaluate change.
4. Implement change.
5. Continuously improve from lessons learned.

Descriptions and suggestions on how to implement each principle are contained in the team's publication (CII SP43-1, 1994).

3.3.4 Metrics

Suggested change management metrics that meet the CII criteria of being measurable, significant, influential, repeatable, and timely include the following (CII SP43-1, 1994).

- Amount of change
- Time available for decision
- Type of change
- Time
- Nature
- Source
- Status of completing the change
- Engineering function or craft trade involved

The above list is not all-inclusive. Any metric that meets the CII criteria can be considered an effective metric.

3.3.5 Recommended Practices

Numerous practices for managing change effectively are recommended for each phase of construction. Below is a list of some recommended construction phase practices and comments on their applicability towards NAVFAC projects (CII SP43-1, 1994).

- *Establish a change management process early.* This needs to be modified for each contract depending on the circumstances.
- *Formulate strategies that, where applicable, ensure that fabrication and construction proceed while changes are being resolved.*" Delaying progress while searching for funding creates unnecessary delay and expense. A proper change management process would address funding issues and other possible administrative delays prior to beginning construction.

- *Use control methods that track the accumulations of changes and their overall effect on the project.* NAVFAC systems currently track modification dollar amounts and time extensions among other things. However, the author is not aware of any control systems that are used to track change impacts such as productivity loss and ripple effect.
- *Be aware that CII research shows that productivity declines with increasing changes.* When preparing pre-negotiation positions, NAVFAC personnel must recognize that loss of productivity is a monetary issue that needs to be addressed during change orders. If given the chance, one must believe that a contractor would rather be honest and attempt to quantify productivity loss than inflate change proposal costs to recover productivity loss or file claims at the end of the job.

3.3.6 Summary: Project Change Management

Implementing effective project change management practices can provide clear change communication throughout all phases of a projects' life cycle. Improved change communication can result in less changes and improved efficiency in processing necessary changes. Ultimately, an effective project change management process can improve customer satisfaction and reduce TIC.

Chapter 4

DATA ANALYSIS

The following data analyses are performed to determine if the implementation of selected best practices results in a reduced project change rate during construction (PCRC). A reduction in the PCRC can result in reduced schedule delays and relief from the administrative burden associated with processing modifications. In the following sections, the z-test will be used to determine the validity of hypothesis 1 and linear regression with *t* distribution analysis will test the validity of hypotheses 2 through 6. The application of both of these statistical tests was described in Section 2.4.

4.1 HYPOTHESIS 1: NAVFAC PCRC VS CII PCRC

Hypothesis 1 states that NAVFAC projects experience a higher PCRC than CII Owner projects. Table 4.1 below compares the PCRC rates of the NAVFAC and CII Owner Version 2 data.

Table 4.1: CII PCRC vs. NAVFAC PCRC

Source	Mean PCRC	PCRC Weighted Average	Median PCRC
CII Owners	5%	5%	3%
NAVFAC	10%	9%	7%
CII Contractors	10%	8%	7%

Using the z-test, it was determined that $|z| = 2.294 > 1.96$. Therefore, the null hypothesis is rejected and the samples were not shown to be the same with 95 percent confidence. If the results are not considered the same, they are considered different. The rejection of the null hypothesis means that hypothesis 1 is accepted.

4.2 CII Owner Version 2 Data Analysis

The following five analyses were performed on CII Owner Version 2 data:

1. Total Cost of Construction vs. PCRC
2. Team Building Index vs. PCRC
3. Constructability Index vs. PCRC
4. Project Change Management Index vs. PCRC
5. Combined Use Index vs. PCRC

Each analysis will be performed separately in the following subsections. For each analysis, a linear regression graph will be used to illustrate the relationship between the PCRC and the best practice. The best fitting line will be represented using a solid line. For graphs were there is a notable reduction in variance as best practice use increases, thick dotted lines will be used to illustrate the reduced variance. Placement of the variance dotted lines will be estimated.

4.2.1 Hypothesis 2: Total Cost of Construction vs. PCRC

Hypothesis 2 stated that the total cost of construction has a negligible effect on the PCRC. Figure 4.1 illustrates the analysis performed to determine the effects of the total cost of construction on the PCRC.

As shown in Figure 4.1, an increase in the total cost of construction tended to result in a slight decrease in the PCRC and no noticeable reduction in variance. However, further analysis of Figure 4.1 reveals there is no statistically significant relationship between the total cost of construction and the PCRC rate since a great deal of PCRC variation exists for most all total construction cost values. Moreover, since $|t| = 0.299 \leq 2.000$, the cost of construction and the PCRC are considered independent.

Therefore, as stated in hypothesis 2, project size had a negligible influence on the PCRC. Hypothesis 2 is statistically accepted for the CII Owner Version 2 data.

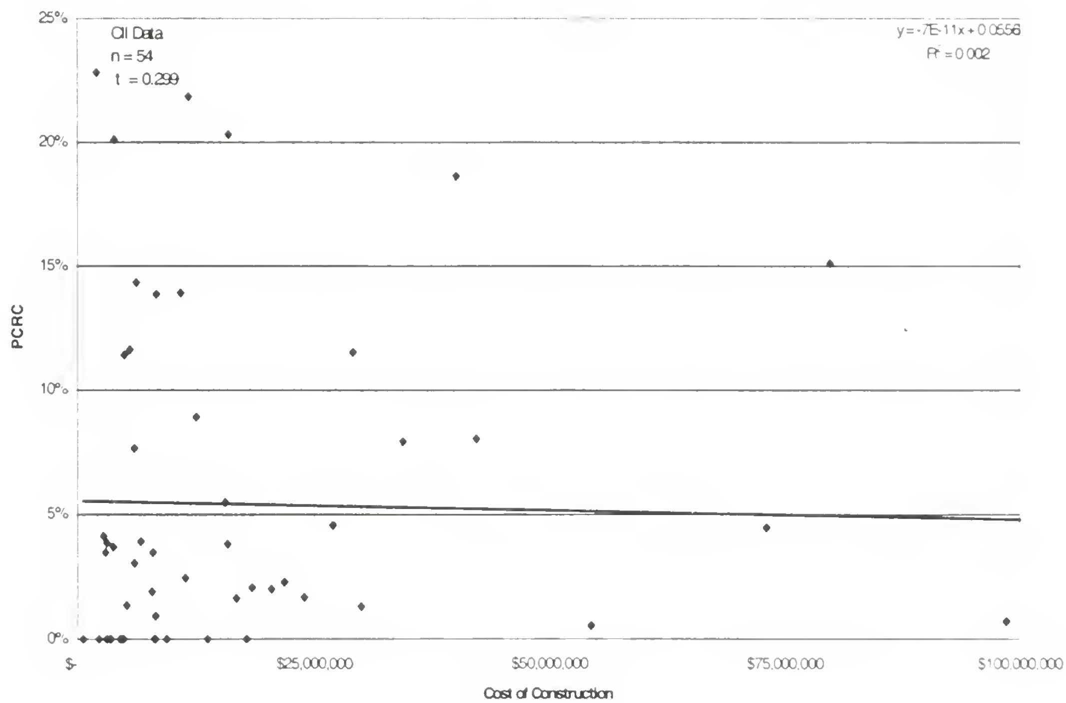


Figure 4.1: Cost of Construction versus PCRC

4.2.2 Hypothesis 3: Team Building Index vs. PCRC

Hypothesis 3 states that the PCRC can be reduced with an increased use of team building. Figure 4.2 below illustrates the analysis performed to determine the effects of team building on the PCRC.

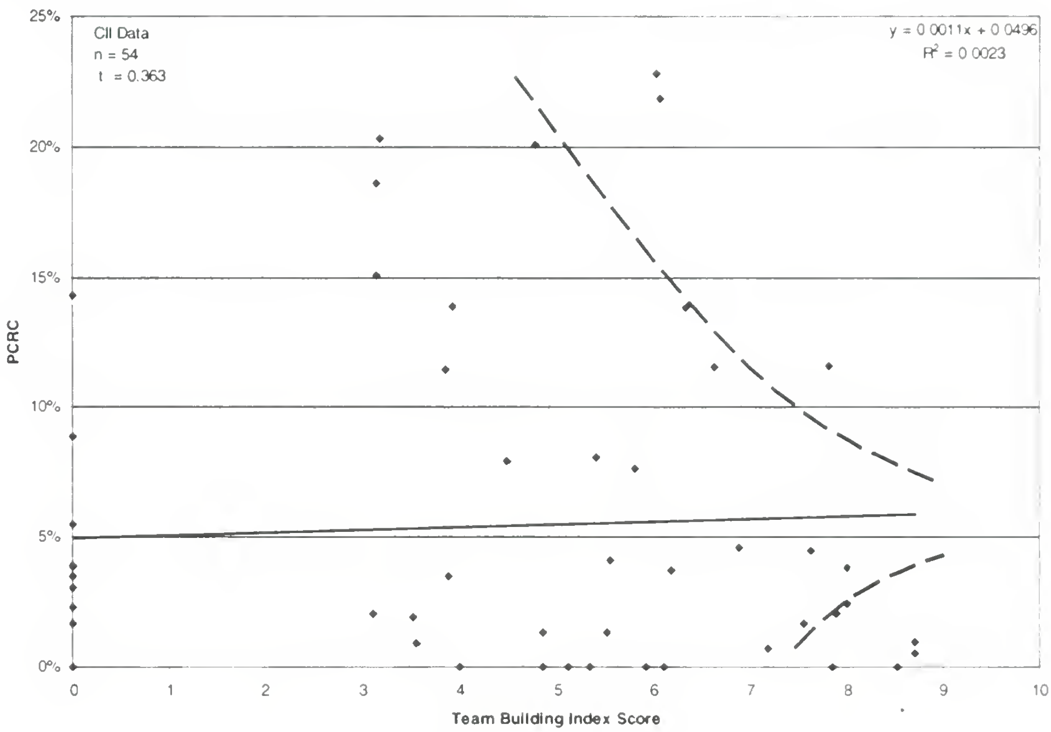


Figure 4.2: Team Building Use versus PCRC

As shown in Figure 4.2, an increase in the use team building tended to result in a slight increase in the PCRC and a slight reduction in variance. This was interesting since it was contrary to hypothesis 3. However, further analysis of Figure 4.2 reveals that there is no statistically significant relationship between team building and the PCRC since a great deal of PCRC variation exists for most

all team building index scores. Moreover, since $|t| = 0.363 \leq 2.000$, team building use and the PCRC are considered independent.

Therefore, a decrease in PCRC can not be attributed to an increased use of team building. Hypothesis 3 is statistically rejected for the CII Owner Version 2 data.

4.2.3 Hypothesis 4: Constructability Index vs. PCRC

Hypothesis 4 states that the PCRC can be reduced with an increased use of constructability. Figure 4.3 below illustrates the analysis performed to determine the effects of constructability on the PCRC.

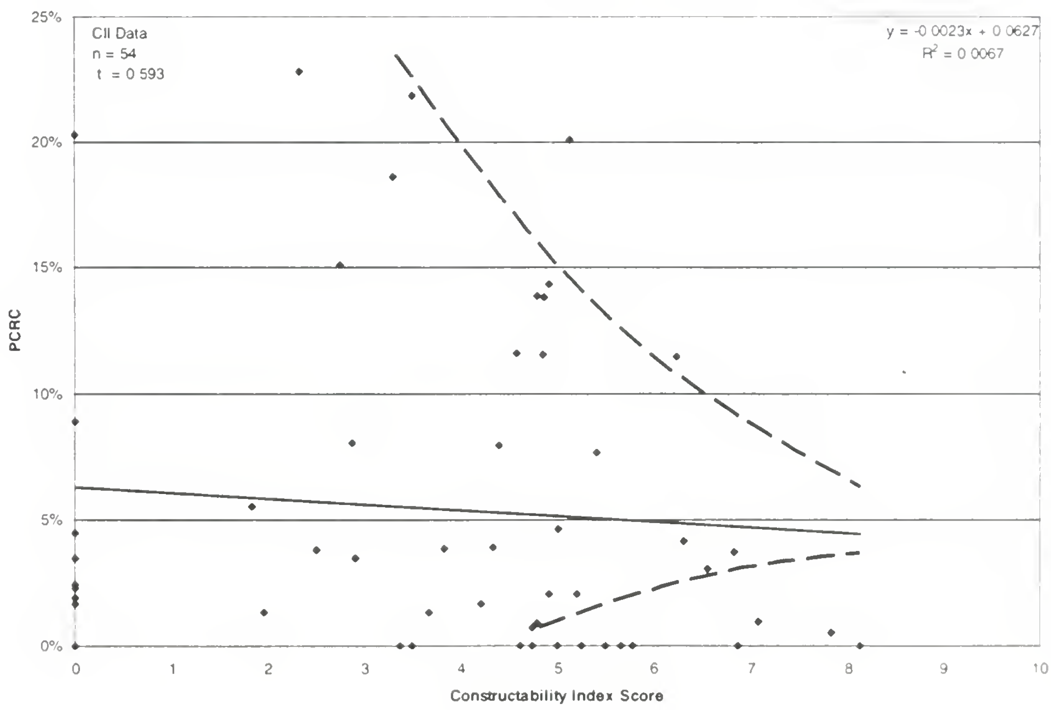


Figure 4.3: Constructability Use versus PCRC

As shown in Figure 4.3, an increase in the use of constructability tended to result in a slight decrease in the PCRC and a notable reduction in variance. However, the analysis in Figure 4.3 reveals that there is no statistically significant relationship between constructability and the PCRC since a great deal of PCRC variation exists for most all constructability index scores. Moreover, since $|t| = 0.593 \leq 2.000$, constructability use and the PCRC are considered independent.

Therefore, a decrease in the PCRC can not be attributed to an increased use of constructability. Hypothesis 4 is statistically rejected for the CII Owner Version 2 data.

4.2.4 Hypothesis 5: Project Change Management Index vs. PCRC

Hypothesis 5 states that the PCRC can be reduced with an increased use of project change management. Figure 4.4 below illustrates the analysis performed to determine the effects of project change management on the PCRC.

As shown in Figure 4.4, an increase in the use of project change management practices tended to result in a slight decrease in the PCRC and no noticeable reduction in variance. However, the analysis in Figure 4.4 reveals that there is no statistically significant relationship between project change management and the PCRC since a great deal of PCRC variation exists for most all project change management index scores. Moreover, since $|t| = 0.751 \leq 2.000$, project change management use and the PCRC are considered independent.

Therefore, a decrease in PCRC can not be attributed to an increased use of project change management. Hypothesis 5 is statistically rejected for the CII Owner Version 2 data.

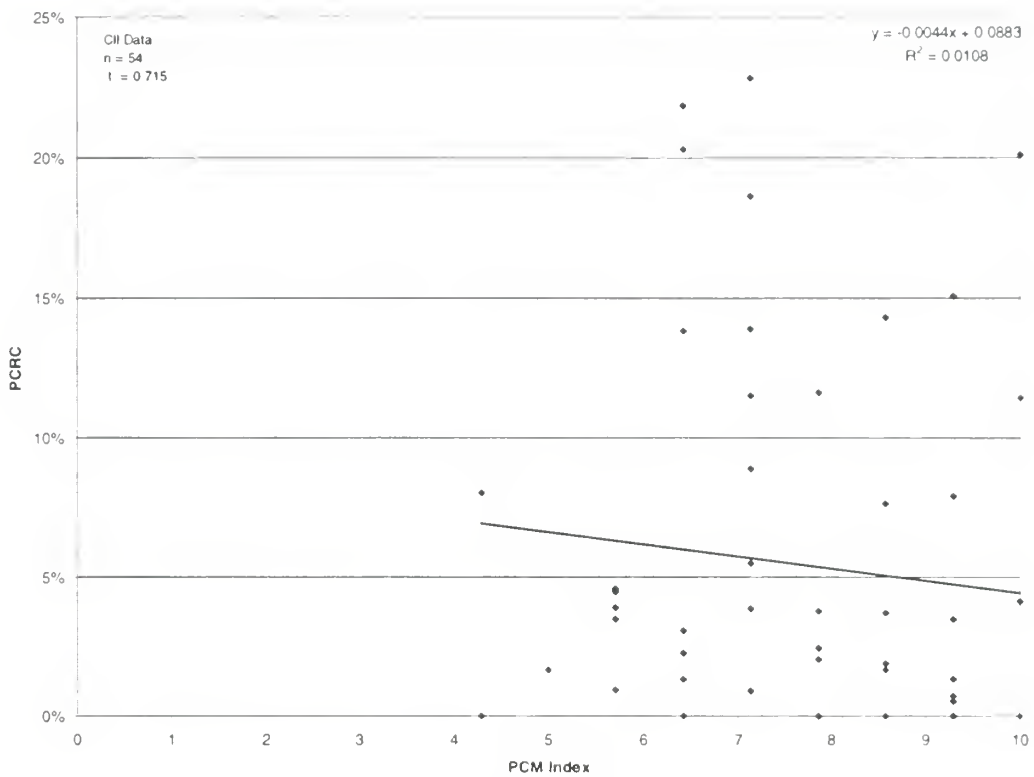


Figure 4.4: Project Change Management use versus PCRC

4.2.5 Hypothesis 6: Combined Use Index vs. PCRC

Hypothesis 6 states that the PCRC can be reduced with an increased combined use of team building, constructability and project change management. Figure 4.5 illustrates the analysis performed to determine the combined effect of using team building, constructability, and project change management on the PCRC.

As shown in Figure 4.5, an increase in the combined use of team building, constructability, and project change management tended to result in a slight decrease in the PCRC and a slight reduction in variance. However, the analysis in

Figure 4.5 reveals that there is no statistically significant relationship between increased combined use and the PCRC since a great deal of PCRC variation exists for most all combined index scores. Moreover, since $|t| = 0.314 \leq 2.000$, combined use and the PCRC are considered independent.

Therefore, a decrease in PCRC can not be attributed to an increased combined use of team building, constructability, and project change management. Hypothesis 6 is statistically rejected for the CII Owner Version 2 data.

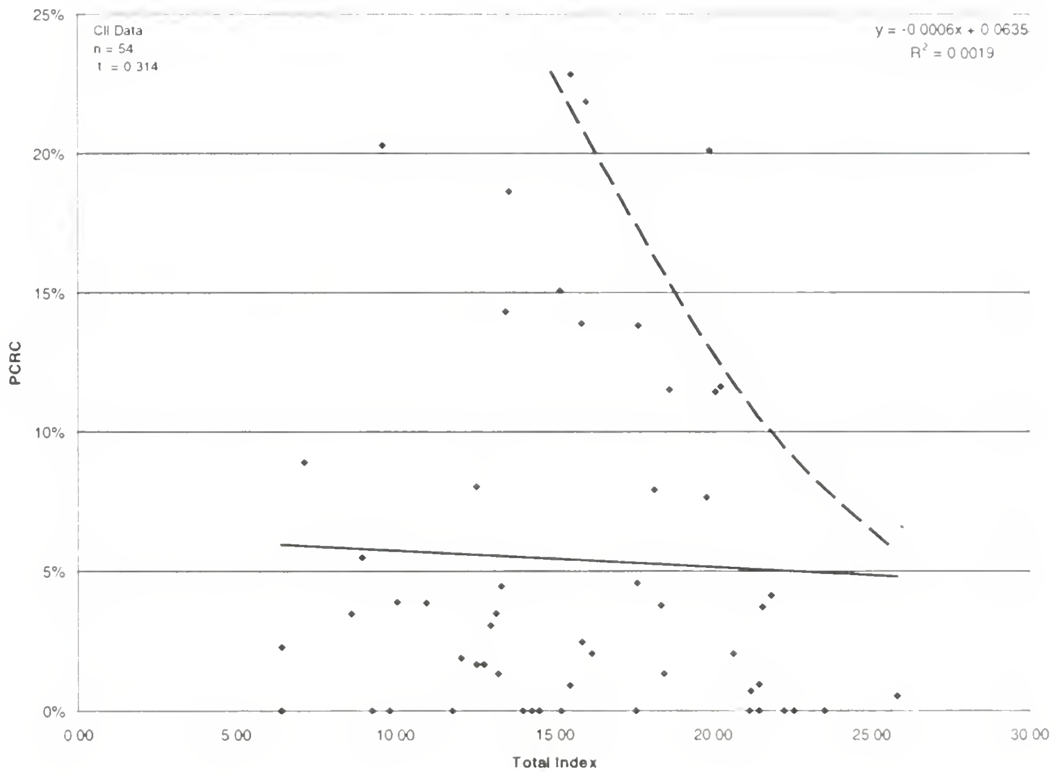


Figure 4.5: Combined Use versus PCRC

4.3 NAVFAC DATA ANALYSIS

The same five analyses that were performed on CII Owner Version 2 data will also be performed on the NAVFAC data to see if any statistically significant relationships can be identified.

For each analysis, a linear regression graph will be used to illustrate the relationship between the PCRC and the best practice. The best fitting line will be represented using a solid line. For graphs were there is a notable reduction in variance as best practice use increases, dotted lines will be used to illustrate the reduced variance. Placement of the variance dotted lines will be estimated.

4.3.1 Hypothesis 2: Total Cost of Construction vs. PCRC

Figure 4.6 below illustrates the analysis performed to determine the effects of the total cost of construction on the PCRC.

As shown in Figure 4.6, an increase in the total cost of construction tended to result in a slight decrease in the PCRC and a significant reduction in variance. However, further analysis of Figure 4.6 reveals there is no statistically significant relationship between the total cost of construction and the PCRC rate since a great deal of PCRC variation exists for most all total construction cost values. Moreover, since $|t| = 0.284 \leq 2.021$, the cost of construction and the PCRC are considered independent.

Therefore, as stated in hypothesis 2, project size had a negligible influence on the PCRC. Hypothesis 2 is statistically accepted for the NAVFAC data. Since hypothesis 2 was proven for both data sets, the significant difference between the

construction cost of the CII projects and the construction cost of the NAVFAC projects should not effect this research.

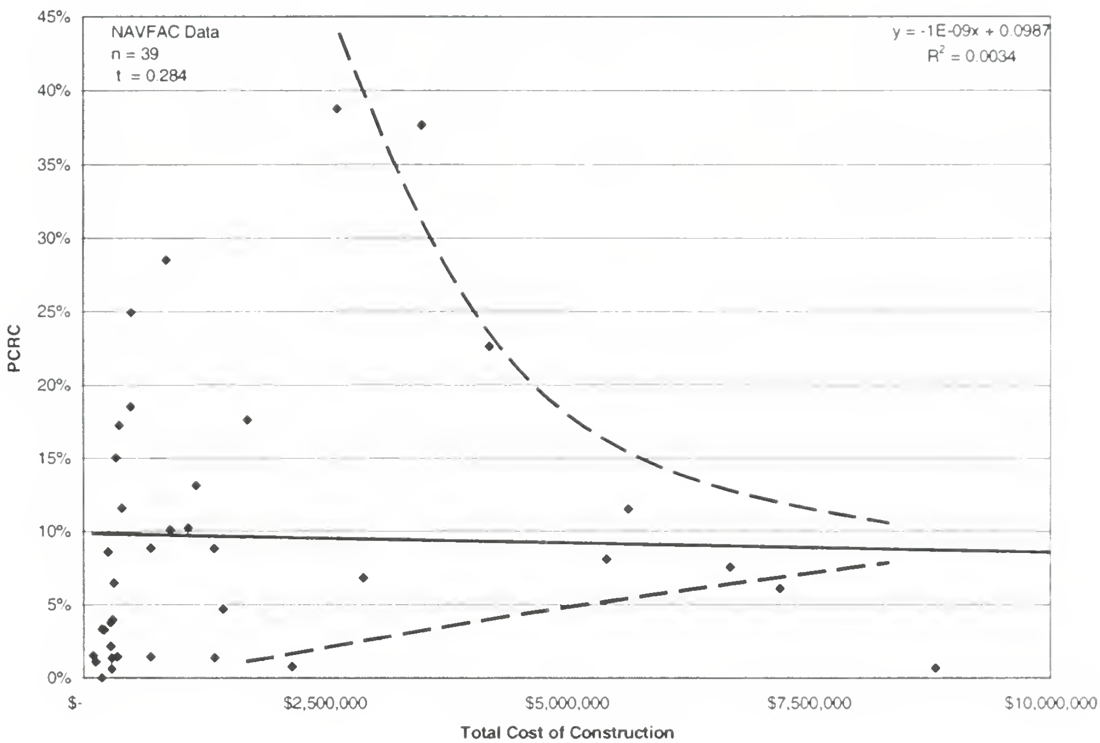


Figure 4.6: Total Cost of Construction versus PCRC

4.3.2 Hypothesis 3: Team Building Index vs. PCRC

Figure 4.7 illustrates the analysis performed to determine the effects of team building on the PCRC. As shown in Figure 4.7, an increase in the use team building tended to result in a slight decrease in the PCRC and a significant reduction in variance. The decreasing PCRC tendency was the opposite of that found during the CII Owner Version 2 data analysis. However, further analysis of Figure 4.7 reveals that there is no statistically significant relationship between team building and the PCRC since a great deal of PCRC variation exists for most

all team building index scores. Moreover, since $|t| = 0.359 \leq 2.021$, team building use and the PCRC are considered independent.

Therefore, a decrease in PCRC can not be attributed to an increased use of team building. Hypothesis 3 is statistically rejected for the NAVFAC data.

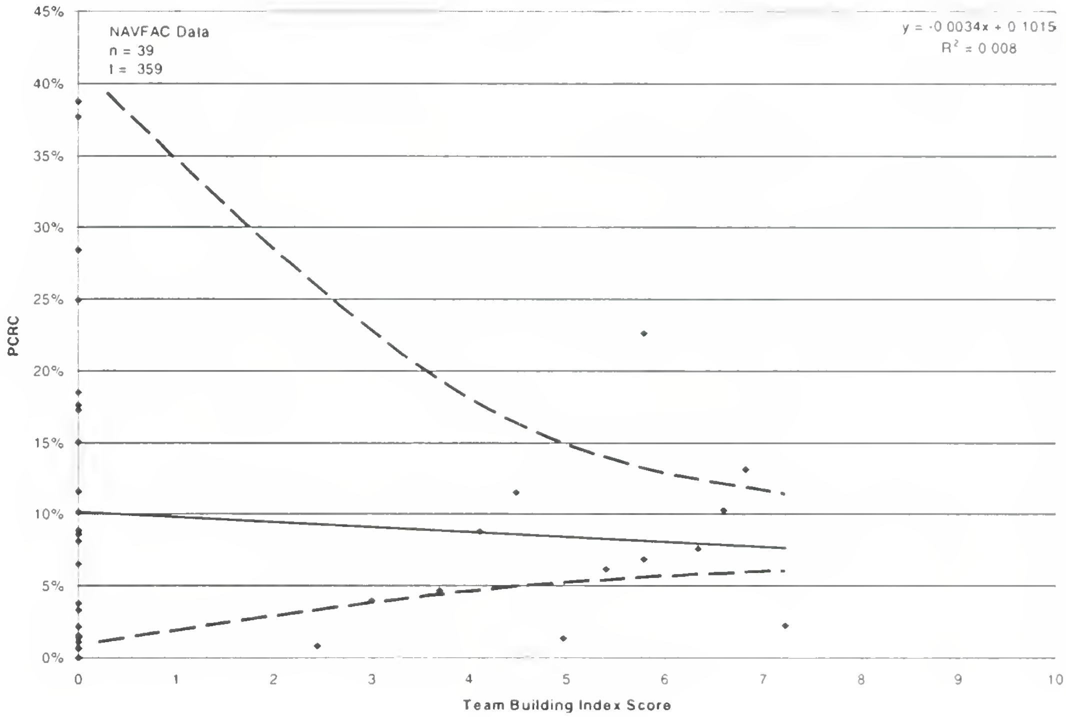


Figure 4.7: Team Building Use versus PCRC

4.3.3 Hypothesis 4: Constructability Index vs. PCRC

Figure 4.8 illustrates the analysis performed to determine the effects of constructability on the PCRC. As shown in Figure 4.8, an increase in the use of constructability tended to result in a slight increase in the PCRC and a slight reduction in variance. This was interesting since it was contrary to both

hypothesis 4 and the CII Owner Version 2 data analysis findings. However, the analysis in Figure 4.8 reveals that there is no statistically significant relationship between constructability and the PCRC since a great deal of PCRC variation exists for most all constructability index scores. Moreover, since $|t| = 0.401 \leq 2.021$, constructability use and the PCRC are considered independent.

Therefore, a decrease in PCRC can not be attributed to an increased use of constructability. Hypothesis 4 is statistically rejected for the NAVFAC data.

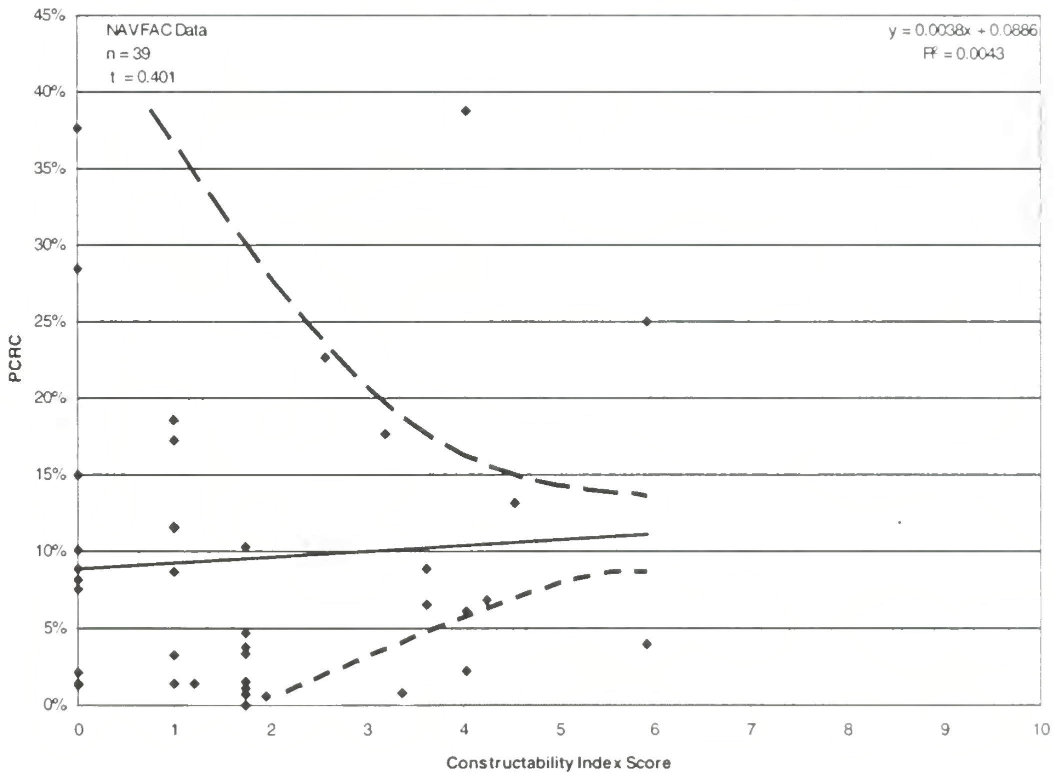


Figure 4.8: Constructability Use versus PCRC

4.3.4 Hypothesis 5: Project Change Management Index vs. PCRC

Figure 4.9 illustrates the analysis performed to determine the effects of project change management on the PCRC. As shown in Figure 4.9, an increase in the use of project change management practices tended to result in a slight increase in the PCRC and no noticeable reduction in variance. Once again, this was contrary to both hypothesis 5 and the CII Owner Version 2 data analysis findings. However, the analysis in Figure 4.9 reveals that there is no statistically significant relationship between project change management and the PCRC since a great deal of PCRC variation exists for most all project change management index scores. Moreover, since $|t| = 0.218 \leq 2.021$, project change management use and the PCRC are considered independent.

Therefore, a decrease in PCRC can not be attributed to an increased use of project change management. Hypothesis 5 is statistically rejected for the NAVFAC data.

4.3.5 Hypothesis 6: Combined Use Index vs. PCRC

Figure 4.10 below illustrates the analysis performed to determine the combined effect of using team building, constructability, and project change management on the PCRC.

As shown in Figure 4.10, an increase in the combined use of team building, constructability, and project change management tended to result in a decrease in the PCRC and a slight reduction in variance. However, the analysis in Figure 4.10 reveals that there is no statistically significant relationship between increased combined use and the PCRC since a great deal of PCRC variation exists

for most all combined index scores. Moreover, since $|t| = 0.086 \leq 2.021$, combined use and the PCRC are considered independent.

Therefore, a decrease in PCRC can not be attributed to an increased combined use of team building, constructability, and project change management. Hypothesis 6 is statistically rejected for the NAVFAC data.

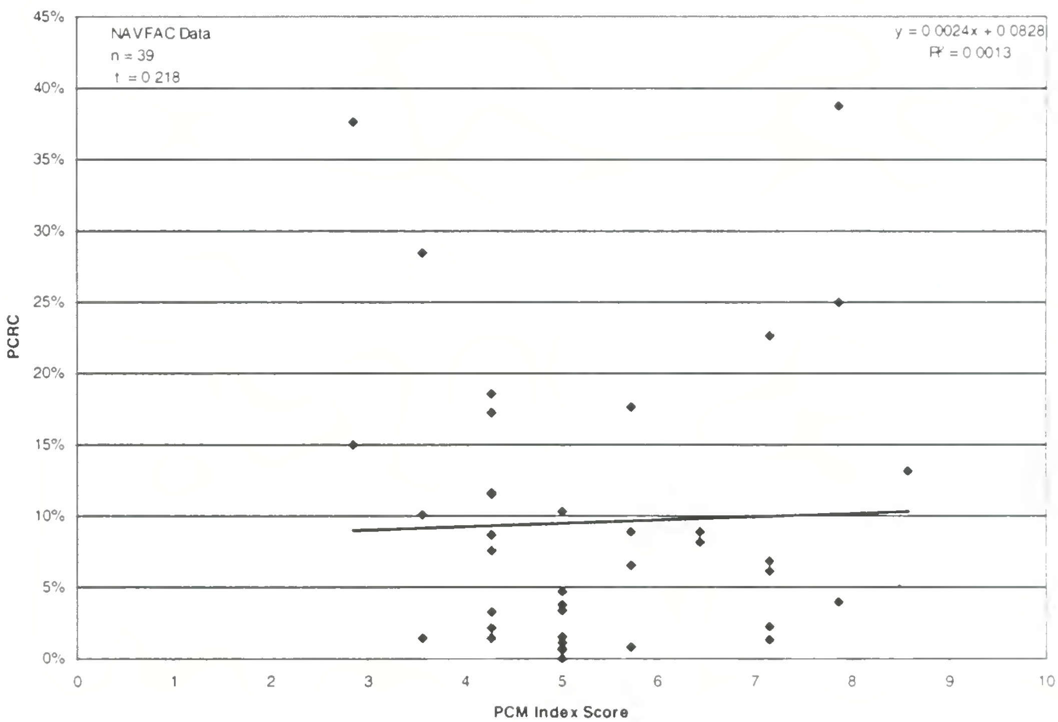


Figure 4.9: Project Change Management Use versus PCRC

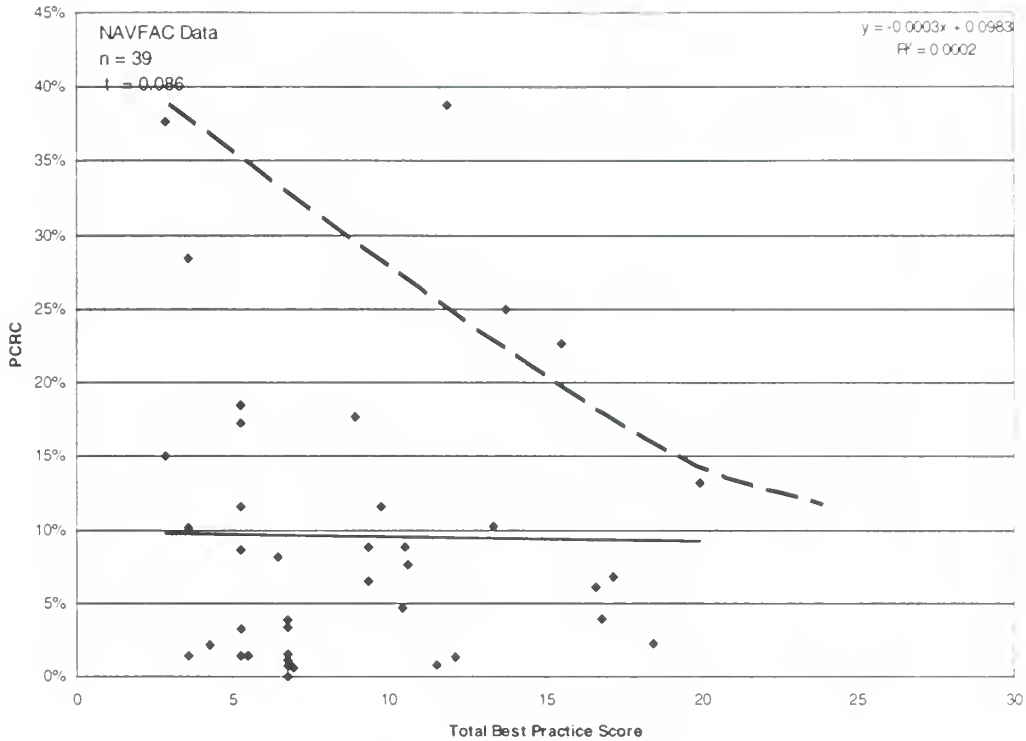


Figure 4.10: Combined Use versus PCRC

4.4 CII CONTRACTOR VERSION 2 DATA ANALYSIS

The same five analyses that were performed on CII Owner Version 2 data and the NAVFAC data will also be performed on the CII Contractor data to see if any statistically significant relationships can be identified.

For each analysis, a linear regression graph will be used to illustrate the relationship between the PCRC and the best practice. The best fitting line will be represented using a solid line. For graphs were there is a notable reduction in variance as best practice use increases, dotted lines will be used to illustrate the reduced variance. Placement of the variance dotted lines will be estimated.

4.4.1 Hypothesis 2: Total Cost of Construction vs. PCRC

Figure 4.11 illustrates the analysis performed to determine the effects of the total cost of construction on the PCRC. As shown in Figure 4.11, an increase in the total cost of construction tended to result in a slight decrease in the PCRC and significant reduction in variance. However, further analysis of Figure 4.11 reveals there is no statistically significant relationship between the total cost of construction and the PCRC rate since $|t| = 0.803 \leq 2.000$.

Therefore, the cost of construction and the PCRC are considered independent and as stated in hypothesis 2, project size had a negligible influence on the PCRC. Hypothesis 2 is statistically accepted for the CII Contractor Version 2 data.

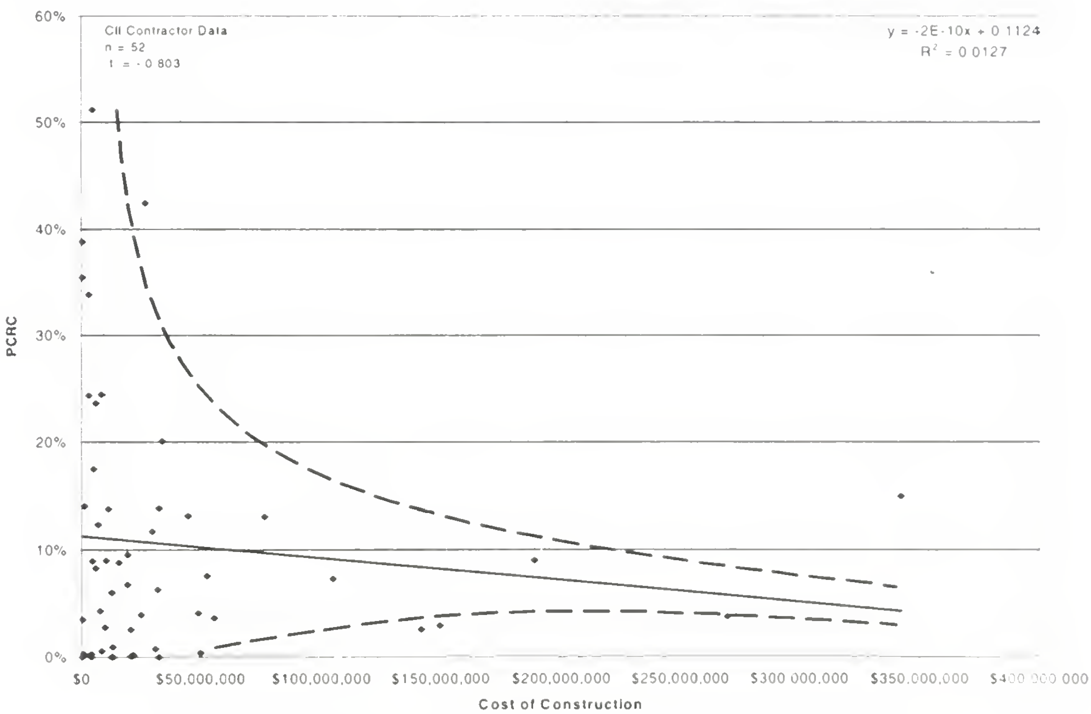


Figure 4.11: Total Cost of Construction versus PCRC

4.4.2 Hypothesis 3: Team Building Index vs. PCRC

Figure 4.12 illustrates the analysis performed to determine the effects of team building on the PCRC. As shown in Figure 4.12, an increase in the use of team building resulted in a consistent decrease in the PCRC and a significant reduction in variance. Further analysis of Figure 4.12 reveals that there is a statistically significant relationship between team building and the PCRC. Since $|t|$ = 3.093 > 2.000, team building use and the PCRC are not considered independent.

Therefore, a decrease in PCRC can be attributed to an increased use of team building. Hypothesis 3 is statistically accepted for the CII Contractor Version 2 data.

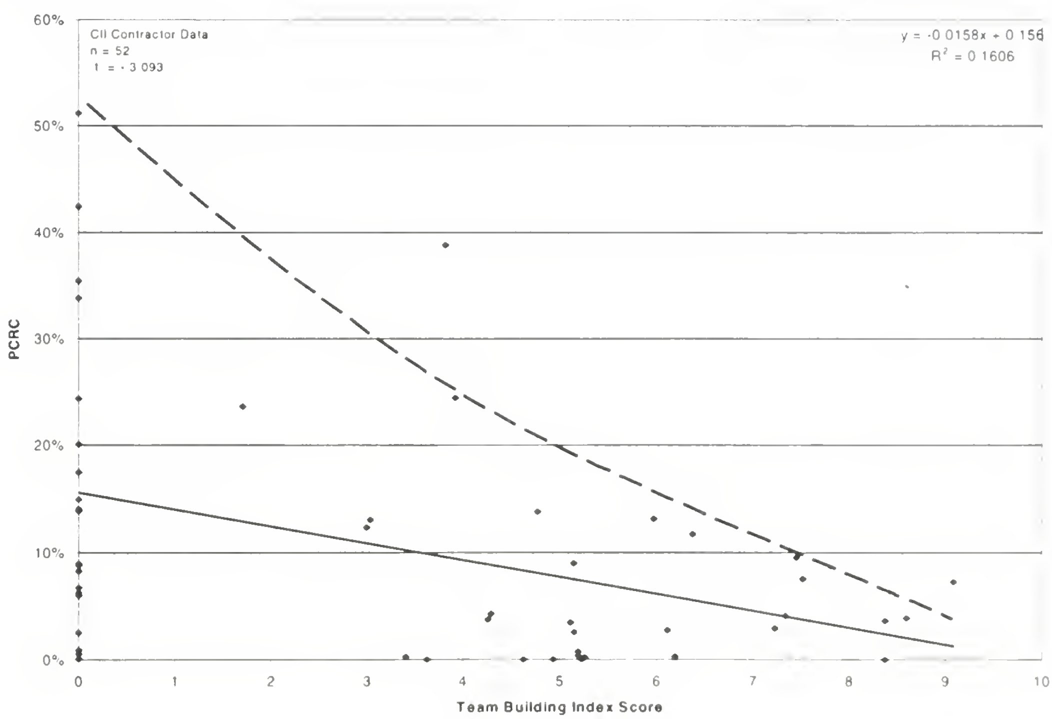


Figure 4.12: Team Building Use versus PCRC

4.4.3 Hypothesis 4: Constructability Index vs. PCRC

Figure 4.13 illustrates the analysis performed to determine the effects of constructability on the PCRC. As shown in Figure 4.13, an increase in the use of constructability resulted in a consistent decrease in the PCRC and a significant reduction in variance. Further analysis of Figure 4.13 reveals that there is a statistically significant relationship between constructability use and the PCRC. Since $|t| = 2.282 > 2.000$, constructability use and the PCRC are not considered independent.

Therefore, a decrease in PCRC can be attributed to an increased use of constructability. Hypothesis 4 is statistically accepted for the CII Contractor Version 2 data.

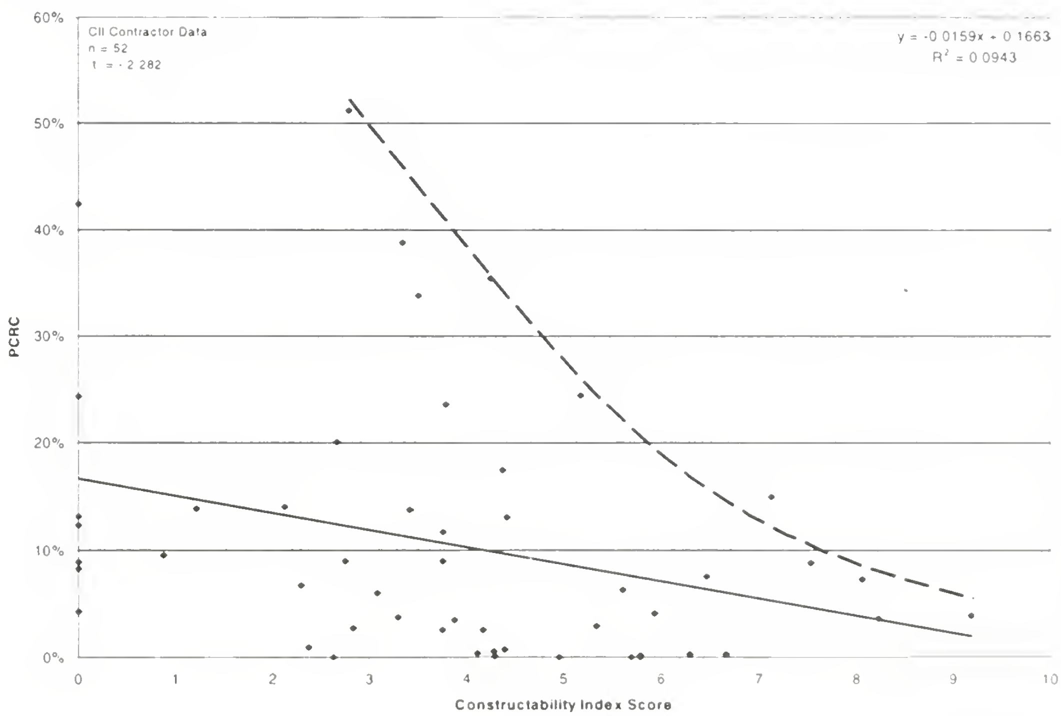


Figure 4.13: Constructability Use versus PCRC

4.4.4 Hypothesis 5: Project Change Management Index vs. PCRC

Figure 4.14 illustrates the analysis performed to determine the effects of project change management on the PCRC. As shown in Figure 4.14, an increase in the use of project change management practices tended to result in a slight decrease in the PCRC and no noticeable reduction in variance. However, further analysis of Figure 4.14 reveals that there is no statistically significant relationship between project change management use and the PCRC since a great deal of PCRC variation exists for most all project change management index scores. Moreover, since $|t| = 0.997 \leq 2.000$, project change management use and the PCRC are considered independent.

Therefore, a decrease in PCRC can not be attributed to an increased use of project change management. Hypothesis 5 is statistically rejected for the CII Contractor Version 2 data.

4.4.5 Hypothesis 6: Combined Use Index vs. PCRC

Figure 4.15 illustrates the analysis performed to determine the combined effect of using team building, constructability, and project change management on the PCRC. As shown in Figure 4.15, an increase in the combined use of team building, constructability, and project change management resulted in a consistent decrease in the PCRC and a significant reduction in variance. Further analysis of Figure 4.15 reveals that there is a statistically significant relationship between increased combined use and the PCRC. Since $|t| = 2.959 > 2.021$, combined use and the PCRC are not considered independent.

Therefore, a decrease in PCRC can be attributed to an increased combined use of team building, constructability, and project change management. Hypothesis 6 is statistically accepted for the CII Contractor Version 2 data.

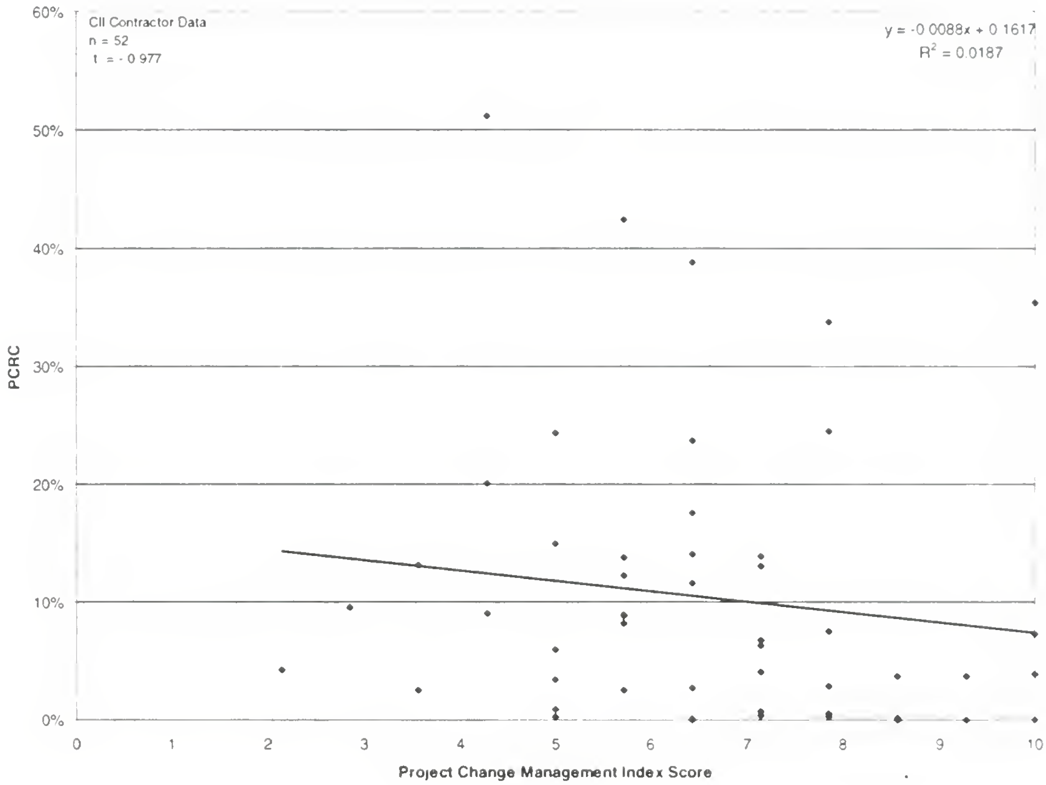


Figure 4.14: Project Change Management Use versus PCRC

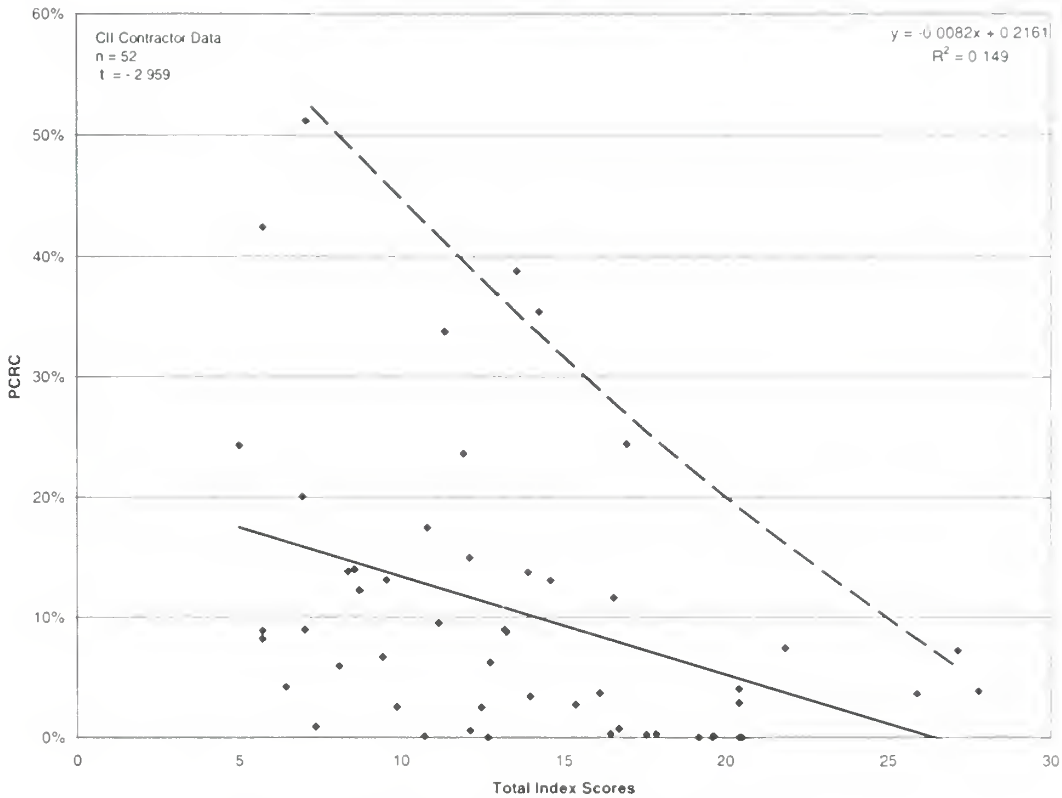


Figure 4.15: Combined Use versus PCRC

4.4.6 Team Building plus Constructability Use Index vs. PCRC

Figure 4.16 illustrates the analysis performed to determine the combined effect of using team building and constructability on the PCRC. This was examined since both team building and constructability use were shown to have an influence on the PCRC. Project change management is not included because the PCRC was shown to be independent of project change management.

As shown in Figure 4.16, an increase in the combined use of team building and constructability resulted in a consistent decrease in the PCRC and a significant reduction in variance. Further analysis of Figure 4.16 reveals that

there is a statistically significant relationship between increased combined use of team building/constructability and the PCRC. Since $|t| = 3.317 > 2.021$, combined use of team building/constructability and the PCRC are not considered independent.

Therefore, a decrease in PCRC can be attributed to an increased combined use of team building and constructability.

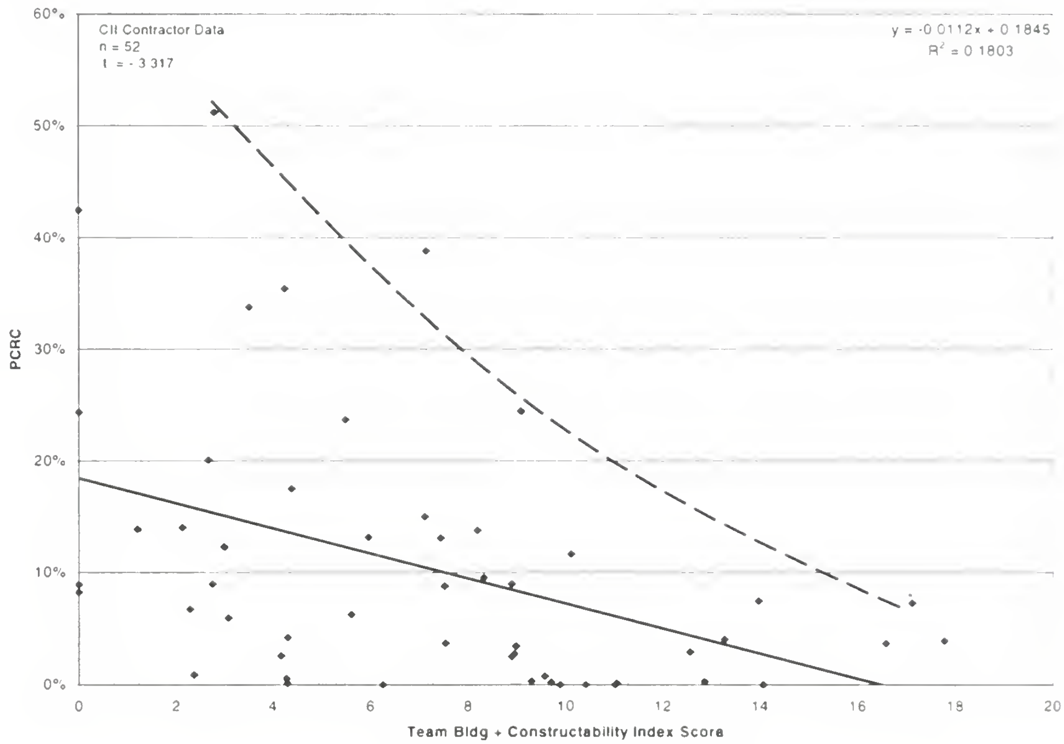


Figure 4.16: Team Building + Constructability Use versus PCRC

4.5 SUMMARY OF FINDINGS

CII Owner, NAVFAC, and CII Contractor results are summarized separately in Tables 4.2, 4.3 and 4.4 below. Each table includes the statistical findings for hypothesis 2 through 6. Hypothesis 1, NAVFAC has a higher PCRC

than CII Owners, was statistically proven in Section 4.1. Each table below shows the calculated t value for that hypothesis, the required t value to prove the null hypothesis (PCRC and best practice are independent), and the statistical conclusion. To assist the reader in understanding the tables, the six hypotheses are listed below.

1. NAVFAC projects experience a higher PCRC than CII Owner projects.
2. The total cost of the construction phase of a project has a negligible effect on the PCRC.
3. The PCRC can be reduced with an increased use of team building.
4. The PCRC can be reduced with an increased use of constructability (C-).
5. The PCRC can be reduced with an increased use of project change management practices.
6. An increase in the combined use of team building, constructability, and project change management will result in a reduced PCRC.

Table 4.2: CII Owners Version 2 Findings

Hypothesis Number	| t | Calculated	$\leq t$ Value	Statistical Decision
2: Size Effect on PCRC	0.299	2.000	Accept
3: TB vs. PCRC	0.363	2.000	Reject
4: C- vs. PCRC	0.593	2.000	Reject
5: PCM vs. PCRC	0.751	2.000	Reject
6: Comb Use vs. PCRC	0.314	2.000	Reject

Table 4.3: NAVFAC Findings

Hypothesis Number	| t | Calculated	T Table	Statistical Decision
2: Size Effect on PCRC	0.284	2.021	Accept
3: TB vs. PCRC	0.359	2.021	Reject
4: C- vs. PCRC	0.401	2.021	Reject
5: PCM vs. PCRC	0.218	2.021	Reject
6: Comb Use vs. PCRC	0.086	2.021	Reject

Table 4.4: CII Contractor Version 2 Findings

Hypothesis Number	| t | Calculated	T Table	Statistical Decision
2: Size Effect on PCRC	0.803	2.021	Accept
3: TB vs. PCRC	3.093	2.021	Accept
4: Construct. vs. PCRC	2.282	2.021	Accept
5: PCM vs. PCRC	0.977	2.021	Reject
6: Comb Use vs. PCRC	2.959	2.021	Accept
TB + C- vs. PCRC	3.317	2.021	Accept

As can be seen in the Tables 4.2 and 4.3, hypotheses 3 through 6 were statistically rejected for both CII Owners and NAVFAC. In short, no relationship

between best practice use and the PCRC could be statistically validated. In contrast, it was statistically validated that CII Contractors that had increased use of team building and constructability did have a lower PCRC (Table 4.4). However, it was not statistically proven that CII Contractors that had an increased use of project change management had a lower PCRC.

Even though it was not statistically proven that CII Owners and NAVFAC reduced their PCRCs by increasing best practice use, some trends present supported hypothesis 3 through 6 while others opposed the hypotheses. Table 4.5 summarizes all trends whether statistically validated or not. The slopes of the trends will be listed in the table. For example, a trend of *slightly negative* means that a slight decrease in PCRC occurred with an increase in best practice use. A trend of *slightly positive* means that a slight increase in PCRC occurred with an increase in best practice use. Trends that were statistically validated will be noted with an asterisk (*) while trends which contradicted the hypothesis were noted with a double asterisks (**).

As can be seen in Table 4.5, even though many of the hypotheses were not statistically validated, the results still supported that increased best practice use generally results in a reduction in the PCRC. Hypothesis 5, project change management, was the only hypothesis analyzed that had no significant support. All other best practice hypotheses were statistically validated by CII Contractor data and generally supported by CII Owner Data and NAVFAC data.

Table 4.5: Slope Trend of Best Practice Use vs. PCRC

Hypothesis Number	CII Owner	NAVFAC	CII Contractor
2: Size Effect on PCRC	Slightly Negative	Slightly Negative	Slightly Negative
3: TB vs. PCRC	Slightly Positive**	Slightly Negative	Negative*
4: C- vs. PCRC	Slightly Negative	Slightly Positive**	Negative*
5: PCM vs. PCRC	Slightly Negative	Slightly Positive**	Slightly Negative
6: Comb Use vs. PCRC	Slightly Negative	Slightly Negative	Negative*
TB + C- vs. PCRC	NA	NA	Negative*

* Denotes a statistically validated trend

** Denotes a trend that contradicts the hypothesis

4.6 DISCUSSION OF RESULTS

The following sections will discuss and attempt to explain the results presented earlier in this chapter. Since CII Owners and NAVFAC shared similar results, they will be discussed together and compared against the CII 1997 Report. CII Contractor data will be discussed separately at the end.

In general, even without statistical significance, there is negative cost growth associated with the increased use of team building, constructability and project change management. It is possible that expansion of the database would provide statistically valid conclusions.

4.6.1 CII Owner and NAVFAC Discussion

It was hypothesized at the beginning of this research that CII Owners experienced a lower PCRC than NAVFAC Owners and an increased use selected best practices would lead to a reduction in the PCRC. Even though the best practice hypotheses were not statistically validated, they were generally supported. Overall, CII Owners did experience nearly a 50 percent reduction in their PCRC, part of which might be explained by an increased use of team building, or constructability. Further research would be required to determine the reasons for the reduced PCRC. Therefore, even though the hypotheses were not statistically proven, they certainly were not disproved.

4.6.2 CII Owner and NAVFAC Findings Compared to 1997 CII Report

At first glance, the CII Owner and NAVFAC findings appear contradictory to the 1997 CII Report where overall project cost growth was shown to have statistically significant relationships with the best practices (CII 1997). However, this contradiction has at least two possible explanations.

One possible explanation for this is illustrated in the cost-influence diagram (Figure 4.17). As can be seen in Figure 4.17, as a project progresses, expenditures are high and one's ability to influence expenditures/cost is significantly reduced. Once a project enters the construction/execute project

phase, little can be done to influence/reduce cost fluctuations. In the 1997 CII Report, cost growth was measured over all phases of the project. In Figure 4.17, it can be seen that influence on cost is very significant during the early stages of a project. Therefore, CII Owners best practice use must reduce cost growth more in the early phases of a project since cost growth during the construction phase is not effected by best practice use. Also, it must be noted that CII Owners experienced a PCRC of about 5 percent while the NAVFAC PCRC was about 10 percent. The lower PCRC for CII Owners could be attributed to early use of best practices, but that was not analyzed in this research.

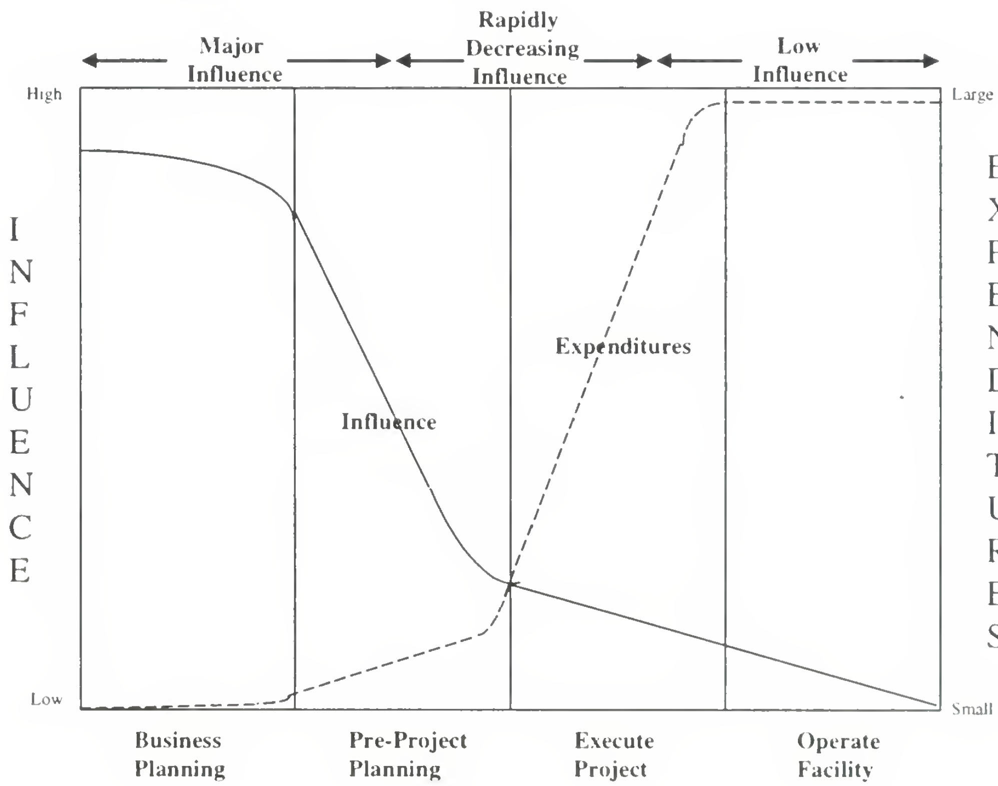


Figure 4.17: Cost Influence Curve

The second possible explanation is that the 1997 CII Report based overall project cost growth on the initial predicted project cost (budget with contingency at the start of detailed design). If proper pre-project planning is performed, an accurate initial budget for the overall project can be determined. Also, by placing contingency in the initial budget, contingency dollars can be spent to effectively hide some cost growth. This study based the CII and NAVFAC PCRC on the absolute value of all changes and the final construction cost. By calculating the PCRC in this manner, no changes are hidden by contingency dollars.

4.6.3 CII Contractor Version 2 Findings

Contrary to the findings of the CII Owners and NAVFAC, statistically significant relationships were established for CII Contractor data. It was shown that for CII Contractor Version 2 data an increase in team building use and constructability use did result in a decrease in the PCRC (no statistically validated relationship between project change management and the PCRC was established). Furthermore, the combined use of team building and constructability use showed the most statistically significant relationship. There are at least two possible explanations for the CII Contractor findings.

When the actual construction contractor is involved with the constructability process, they will tend to score the use of constructability higher. Involving the actual contractor in the constructability review process significantly improves the results. The actual contractor generally has more experience in the construction process and knows which methods and materials are most compatible with his/her company. By meeting with the actual contractor

regularly to discuss constructability issues, owners can receive advanced notice of potential problems before they occur. Early identification of potential problems allows for ample time to implement change at a minimum cost. When outside contractors are used, the Owner may still score constructability use high, but the actual contractor may not. This possibly explains why higher constructability use scores by owners have less meaning than higher constructability use scores by the actual contractor.

The second reason deals with team building use. When contractors feel that they are part of a team, they are more willing to work with the owner then against. When the owner takes an "us against them" mentality and doesn't respect the contractor's knowledge, the contractor will be insulted and less willing to efficiently implement changes. Having the actual contractor as a member of the owner's team provides open channels of communication allowing for advanced notice of potential change. By respecting the contractor's knowledge as a team member, the owner creates an atmosphere that motivates the contractor to provide the most economical and efficient solution possible. If the contractor feels that he/she is part of the team and is getting compensated for hidden costs, the potential for claims after the project is significantly reduced. This explains why higher team building use scores by owners have less meaning than higher team building scores by contractors. If the contractor does not believe that he/she is part of the team, what the owner thinks is occurring with regards to team building is of little use.

Finally, it is no surprise that both team building use and constructability use have similar results since these best practices are interrelated. For a project to score high in constructability, some form of team building must be present.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Changes during the construction phase of a project are generally considered inevitable. However, the ability to minimize the potential for changes can greatly improve the chances of finishing a project within budget and on schedule. For changes that cannot be avoided, identifying early warning signs of project change allows an organization additional time to acquire needed contingency funding for upcoming changes. Also, a thorough knowledge of the impacts of change can better prepare an individual for pricing and negotiating changes that do occur. The following sections address conclusions concerning best practice use based on the results obtained from CII Owners, NAVFAC, and CII Contractors data.

5.1.1 Conclusions Based On CII Owners Data

The conclusions below are for each of the six hypotheses discussed in Chapter 1. These conclusions are based on CII Owner data only.

- Hypothesis 1: CII Owners experienced a lower PCRC than NAVFAC.
- Hypothesis 2: There was no statistically valid relationship between project size and the PCRC. Although a slight decreasing trend in the PCRC was present as the cost of the project increased, comparisons of the data are not invalidated by project size differences.

- Hypothesis 3: There was no statistically valid relationship between increased use of team building and the PCRC. Conversely, a slight increasing trend in the PCRC was present as the use of team building increased.
- Hypothesis 4: There was no statistically valid relationship between increased use of constructability and the PCRC. However, a slight decreasing trend in the PCRC was present as the use of constructability increased.
- Hypothesis 5: There was no statistically valid relationship between increased use of project change management and the PCRC. However, a slight decreasing trend in the PCRC was present as the use of project change management increased.
- Hypothesis 6: There was no statistically valid relationship between increased combined use of all best practices and the PCRC. However, a slight decreasing trend in the PCRC was present as the combined use of all best practices increased.

5.1.2 Conclusions Based On NAVFAC Data

The conclusions below are for each of the six hypotheses discussed in Chapter 1. These conclusions are based on NAVFAC data only.

- Hypothesis 1: NAVFAC experienced a higher PCRC than CII Owners.
- Hypothesis 2: There was no statistically valid relationship between project size and the PCRC. Although a slight decreasing trend in the PCRC was present as the cost of the project increased, comparisons of the data are not invalidated by project size differences.

- Hypothesis 3: There was no statistically valid relationship between increased use of team building and the PCRC. However, a slight decreasing trend in the PCRC was present as the use of team building increased.
- Hypothesis 4: There was no statistically valid relationship between increased use of constructability and the PCRC. Conversely, a slight increasing trend in the PCRC was present as the use of constructability increased.
- Hypothesis 5: There was no statistically valid relationship between increased use of project change management and the PCRC. Conversely, a slight increasing trend in the PCRC was present as the use of project change management increased.
- Hypothesis 6: There was no statistically valid relationship between increased combined use of all best practices and the PCRC. However, a slight decreasing trend in the PCRC was present as the combined use of all best practices increased.

5.1.3 Conclusions Based On CII Contractor Data

The conclusions below are for each of the six hypotheses discussed in Chapter 1. These conclusions are based on CII Contractor data only.

- Hypothesis 1: CII Contractors experienced a similar PCRC as NAVFAC. However, hypothesis 1 only compared CII Owners with NAVFAC.
- Hypothesis 2: There was no statistically valid relationship between project size and the PCRC. Although a slight decreasing trend in the PCRC was present as the cost of the project increased, comparisons of the data are not invalidated by project size differences.

- Hypothesis 3: There was a statistically valid relationship between increased use of team building and a reduction of the PCRC.
- Hypothesis 4: There was a statistically valid relationship between increased use of constructability and a reduction in the PCRC.
- Hypothesis 5: There was no statistically valid relationship between increased use of project change management and the PCRC. However, a slight decreasing trend in the PCRC was present as the use of project change management increased.
- Hypothesis 6: There was a statistically valid relationship between increased combined use of all best practices and a reduction in the PCRC.
- Additional Study: There was a statistically valid relationship between increased combined use of team building and constructability and a reduction in the PCRC.

5.2 RECOMMENDATIONS

The majority of these recommendations are directed toward the NAVFAC community with some final recommendations on further research in this area.

- After reviewing the early warning signs for project change (Oberlender, 1993), it is evident that NAVFAC's current method of bid solicitation will result in an increase in the PCRC and schedule growth. It is recommended that NAVFAC move towards using more approved bidder lists and award on best value rather than low bid.

- NAVFAC should recognize the warning signs for project change and reserve needed contingency funding prior to beginning construction to avoid unnecessary delay.
- NAVFAC personnel must clearly understand the impacts of project change, such as productivity loss, when negotiating changes (Allen, 1995). Failure to acknowledge and compensated all legitimate financial impacts incurred by the contractor can result in over-priced change proposals, more changes, and future claims.
- It is recommended that NAVFAC personnel learn more about the impacts of project change, especially productivity loss.
- When considering the entire life of a project, use of team building and constructability is most effective when it is implemented during pre-project planning.
- When considering the construction phase only, the construction contractor's connection with the best practice being used is essential. It was shown that in relation to the PCRC, the owner's scoring of team building and constructability was not as significant as that of the contractor. NAVFAC needs to convince the construction contractor that he/she is part of the team through team building. Also, NAVFAC should involve the construction contractor in the constructability process as soon as possible.
- NAVFAC readers are encouraged to perform a more thorough literature review and to perform a similar analysis using data within their organization.

- When considering further research in this area, more data might provide statistical validation for the hypotheses that only had general support. Increased data would also reduce the impact of projects that had extenuating circumstances that increased the PCRC.
- More research should be performed to determine the reasons that CII Owners had a significantly lower PCRC than NAVFAC.
- More research should be performed to determine why CII Contractors data provided statistically significant results and CII Owners did not.
- The absolute value of deductive modifications should be used when calculating the PCRC.

Appendix A

NAVFAC QUESTIONNAIRE

The data collected by this form will be used for a thesis to analyze NAVFAC project change management during the construction phase only. NAVFAC results will be compared to data collected from several other civilian companies (CII's benchmarking and metrics system). The data will be used to establish performance norms, to identify trends, and to correlate execution of project change management processes to project outcomes. Through such correlation across many companies and projects, opportunities for improving NAVFAC's project change management performance will be identified. **All data will be held in strict confidence and will not be used to identify weaknesses within individual ROICC offices.** Please provide accurate information.

When you have completed the questionnaire, please return it NLT **March 9, 1998** to the address shown below:

LT Brian Ciaravino
12113 Metric Blvd #1617
Austin, TX 78758

The next two pages contain definitions for project phases. Please pay particular attention to the start and stop points which have been highlighted. Not all definitions may be required, but are provided for clarification as needed. All project costs should be given in U.S. dollars. If you need further assistance in interpreting the intent of a question, please call LT Brian Ciaravino at (512) 832-6674 (E-mail: bciaravino@mail.utexas.edu). Remember, conformance to the instructions and phase definitions is crucial for establishing reliable benchmarks.

Please provide information for 10 projects which were completed between 1995 and 1998. If possible, only use projects with a construction cost of greater than $500,000 and include at least five projects greater than $1,000,000 in construction cost. If the information required to answer a given question is not available, please write "UNK" (unknown) in the space provided. If the information requested does not apply to this project, please write "NA" (not applicable) in the space provided. However, keep in mind that too many "unknowns" or "not applicables" could render the project unusable for analysis.

This form should be completed under the direction of the ROICC project manager who administered the project if possible. The project manager should consult with colleagues who worked on the project. We urge that you carefully review the phase table on the next two pages before attempting to provide the requested information. Also, the question numbers match those of previous surveys that included additional aspects of project management. Therefore, the question numbers will not always be sequential.

Project Change Management
Completed Project Data: EFA West

1. Your Command: ____

2. Your Project I.D. ______________________________ (You may use any reference to protect the project's identity. The purpose of this I.D. is to help you and me identify the questionnaire correctly if clarification of data is needed and to prevent duplicate project entries.)

3. Project Location: ____ , CA
Base

4. Contact Person (name of the person filling out this form): ________________________

5. Contact Phone No. (   ) ________________ 6. Contact Fax No. (   ) __________

7. Principal Type of Project (Check only one. If you feel the project does not have a principal type, but is an even mixture of two or more of those listed, please attach a short description of the project. If the project type does not appear in the list, please describe in the space next to "Other."):

Industrial	Infrastructure	Buildings
______Electrical (Generating)	____Electrical Dist	_____Lowrise Office
______Oil Exploration/Prod	____Highway	_____Highrise Office
______Oil Refining	____Navigation	_____Warehouse
______Pulp and Paper	____Flood Control	_____Hospital
______Chemical Mfg.	____Rail	_____ Laboratory
______Environmental	____Water/Wastewater	_____School
______Pharmaceuticals Mfg.	____ Airport	_____Prison
______Metals Refining/Proc	____Tunneling	_____Hotel
______Microelectronics Mfg.	____Marine Facilities	_____Maintenance Facilities
______Consumer Products Mfg.	____Mining	_____Parking Garage
______Natural Gas Processing		_____Retail
______Automotive Mfg.		
______Foods		

______Other (Please describe)____

8. This project was (check only one): Grass Roots_____ Modernization _____Addition _____

Grass roots - a new facility from the foundations and up. A project requiring demolition of an existing facility before new construction begins is also classified as grass roots.

Modernization - a facility for which a substantial amount of the equipment, structure, or other components is replaced or modified, and which may expand capacity and/or improve the process or facility.

Addition - a new addition that ties in to an existing facility, often intended to expand capacity.

_____ Other (Please describe)____

9a. Please indicate the method of ***acceptance testing*** used on this project.

_____ No Assessment

_____ Demonstrated operations at achieved level

_____ Formal documented acceptance test over a meaningful period of time

9b. Please indicate how the achieved capacity of the completed facility compares against expectations documented in the project execution plan. If the achieved capacity is much worse or much better than expected, please briefly comment on the primary cause of the deviation.

_____ Much worse than expected Why? ____________________

_____ Worse than expected ________________________________

_____ As expected

_____ Better than expected

_____ Much better than expected Why? ____________________

10. **Project Participants**. Please list the construction companies that helped execute this project, but do not list any subcontractors. Indicate the function(s) each company performed and the approximate percent of that function to the nearest 10%. For each function, indicate the principle form of remuneration in use at the completion of the work. Please indicate if each participant was an alliance partner and if their contract contained incentives. For most Government projects, only one prime contractor will be listed.

Please use the following codes to identify the **Function** performed by each project participant.

PPP	Pre-Project Planner	DM	Demolition/Abatement Contractor
PPC	Pre-Project Planning Consultant	GC	General Contractor
D	Designer	PC	Prime Contractor
PE	Procurement – Equipment	PM	Project Manager
PB	Procurement – Bulks	CM	Construction Manager

Percent of Function refers to the percent of the overall function contributed by the company listed. Estimate to the nearest 10 percent.

Type of Remuneration refers to the overall method of payment. Unit price refers to a price for in place units of work and does not refer to hourly charges for skill categories or time card mark-ups. Hourly rate payment schedules should be categorized as cost reimbursable. Please use the following codes to identify remuneration type. Record the form of remuneration for your own company's contribution, if any, as "I" (In House).

LS	Lump Sum	GP	Guaranteed Max Price
UP	Unit Price	I	In-house
CR	Cost Reimbursable/Target Price (Including Incentives)		

An ***Alliance Partner*** is a company with whom your company has a long-term formal strategic agreement that ordinarily covers multiple projects. Circle "Y" to indicate that a company was an alliance partner or circle "N" if the company was not an alliance partner. For Government contracts the response is no.

If **Contract Incentives** were utilized, please indicate whether those incentives were positive (a financial incentive for attaining an objective), negative (a financial disincentive for failure to achieve an objective), or both. Circle "+" to indicate a positive incentive and circle "-" to indicate a negative incentive.

Construction Prime Company Name	Function	Approx Percent of Function (Nearest 10%)	Type of Remun. (Contract End)	Was this company an alliance partner? (No)		Contract Incentives (circle as many as apply)							
						Cost		Schedule		Safety		Quality	
					N	+	-	+	-	+	-	+	-
					N	+	-	+	-	+	-	+	-
					N	+	-	+	-	+	-	+	-

Project Change Management
Completed Project Data: EFA West

13. Please indicate the awarded/budgeted and actual costs of the construction phase

- Construction budget amounts should correspond to the estimate at the start of detailed design.
- Refer to the table on pages 2 and 3 for phase definitions and typical cost elements.
- State the construction cost in U.S. dollars to the nearest $1000. (You may use a "k" to indicate thousands in lieu of "…,000".)
- Include the cost of bulk materials in construction and the cost of engineered equipment in procurement.
- If this project did not involve Demolition/Abatement please write "NA" for that phase.

Construction Phases	Phase Award/Budget (Including Contingency)	Amount of Contingency in Budget	Actual Phase Cost
Demolition/Abatement	$	$	$
Construction	$	$	$
Totals	$	$	$

14. Planned and Actual Project Construction Schedule

- The dates for the planned schedule should be those in effect at the time of award. If you cannot provide an exact day for either the planned or actual, estimate to the nearest week in the form mm/dd/yy; for example, 1/8/96, 2/15/96, or 3/22/96.)
- Refer to the chart on pages 2 and 3 for a description of starting and stopping points for each Phase.
- If this project did not involve Demolition/Abatement please write "NA" for that phase.

Project Phase	Planned Schedule		Actual Schedule	
	Start mm / dd / yy	Stop mm / dd / yy	Start mm / dd / yy	Stop mm / dd / yy
Demolition/Abatement	/ /	/ /	/ /	/ /
Construction	/ /	/ /	/ /	/ /

14b. What percentage of the total engineering workhours for design were completed prior to start of the construction phase? (Write "UNK" in the blank if you don't have this information)

___________ %

15. ***Project Development Changes*** and ***Scope Changes.*** Please record the changes to your project by phase in the table provided below. For each phase indicate the total number, the net cost impact, and the net schedule impact resulting from project development changes and scope changes. Changes may be initiated by either the owner or contractor.

Project Development Changes include those changes required to execute the original scope of work.

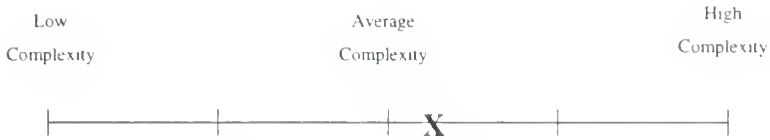
Scope Changes include changes in the base scope of work.

- Changes should be included in the phase in which they were initiated. Refer to the table on pages 2 and 3 to help you decide how to classify the changes by project phase. If you cannot provide the requested change information by phase, but can provide the information for the total project please indicate the totals.
- Indicate "minus" (–) in front of cost or schedule values, if the net changes produced a reduction. If no changes were initiated during a phase, write "0" in the "Total Number" columns.
- State the cost of changes in U.S. dollars to the nearest $1000 and the schedule changes to the nearest week. You may use a "k" to indicate thousands in lieu of "...,000".

Project Phase	Total Number of Project Development Changes	Total Number of Scope Changes	Net Cost Impact of Project Development Changes ($)	Net Cost Impact of Scope Changes ($)	Net Schedule Impact of Project Development Changes (weeks)	Net Schedule Impact of Scope Changes (weeks)
Demolition/ Abatement			$	$	wks	wks
Construction			$	$	wks	wks
Totals			$	$	wks	wks

17b. Project Complexity

Place a mark anywhere on the scale below that best describes the level of complexity for this project as compared to other projects from the same industry sector. For example, if this is a heavy industrial project, how does it compare in complexity to other heavy industrial projects. Use the definitions below the scale as general guidelines.



- **Low Complexity -** Characterized by the use of no unproven technology, small number of process steps, small facility size or process capacity, previously used facility configuration or geometry, proven construction methods, etc.

- **High Complexity -** Characterized by the use of unproven technology, an unusually large number of process steps, large facility size or process capacity, new facility configuration or geometry, new construction methods, etc.

Project Change Management
Completed Project Data: EFA West

Team Building Practices

Team Building is a process that brings together a diverse group of project participants and seeks to resolve differences, remove roadblocks and proactively build and develop the group into an aligned, focused and motivated work team that strives for a common mission and for shared goals, objectives and priorities.

36. Was a team building process used for this project? Yes ______ No _______

If yes, answer questions 36a - 36h. If no, go to question 37.

	Yes	No	
36a.	___	___	Was an independent consultant used to facilitate the team building process?
36b.	___	___	Was a team-building retreat held early in the life of the project?
36c.	___	___	Did this project have a documented team-building implementation plan?
36d.	___	___	Were objectives of the team building process documented and clearly defined?

36e. Were team building meetings held among team members throughout the project?

______ Regularly ______ Sometimes ______ Seldom ______ Never

36f. Were follow-up sessions held to integrate new team members and reinforce concepts?

______ Regularly ______ Sometimes ______ Seldom ______ Never

36g. Please indicate the project phases in which team building was used. (Check all that apply)

____ Pre-Project Planning
____ Design
____ Procurement
____ Construction
____ Startup

36h. Please indicate the parties involved in the team building process. (Check all that apply)

____ Owner
____ Designer(s)
____ Contractor(s)
____ Major Suppliers
____ Subcontractor(s)
____ Construction Manager
____ Other. If other, please specify______________________________

Project Change Management
Completed Project Data: EFA West

Constructability Practices

Constructability is the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. Constructability is achieved through the effective and timely integration of construction input into planning and design as well as field operations.

37. Was Constructability implemented on this project? Yes ______ No _______

If yes, please respond to the following statements (37a-37l). If no, go to question 38.

37a. Which of the following best describes the constructability program designation for this project?

____ No designation
____ Part of standard construction management activities
____ Part of another program, such as Quality or only identified on a project level
____ Recognized on a corporate level, but may be part of another program
____ Stand-alone program on same level as Quality or Safety

37b. Which of the following best describes the constructability training of personnel for this project?

____ None
____ If any occurs, done as on-the-job training
____ Awareness seminar(s)
____ Part of standard orientation
____ Part of standard orientation; deeply ingrained in corporate culture

37c. Which of the following best describes the role of the constructability coordinator for this project?

____ Coordinator not identified
____ Part-time if identified; very limited responsibility
____ Informal full- or part-time position; responsibilities vary
____ Formal full- or part-time position; responsibilities vary
____ Full-time position; plays major project role

37d. Which of the following best describes the constructability program documentation for this project?

____ None; CII documents may be available
____ Limited reference in any manual; CII documents may be distributed or referenced
____ Project-level constructability documents exist; may be included in other corporate documents
____ Project constructability manual is available
____ Project constructability manual is thorough, widely distributed, and periodically updated

37e. Which of the following best describes the nature of project-level efforts and inputs concerning constructability for this project?

____ None
____ Reactive approach, constrained by review mentality, poor understanding of proactive benefit
____ Aware of major benefits, proactive approach
____ Proactive approach; routinely consult lessons learned
____ Aggressive, proactive approach from beginning of project; routinely consult lessons learned

37f. Which of the following best describes the implementation of constructability concepts on this project?

____ Very little concept implementation
____ Some concepts used periodically; often considered too late to be of use
____ Selected concepts applied regularly; full use, timeliness of input varies
____ All concepts consistently considered; timely implementation of feasible concepts
____ All concepts consistently considered, continuously evaluated, aggressively implemented

37g. Constructability ideas on this project were collected by: (Check as many as apply)

_____ Suggestion Box
_____ Interviews
_____ Review Meetings
_____ Questionnaire
_____ Other Methods ____
_____ Not Collected

37h. To what extent was a computerized constructability database utilized for this project?

_____ None
_____ Minimal
_____ Moderate
_____ Extensive

37i. Please characterize the frequency of the constructability reviews and discussions for this project.

_____ Once a Week
_____ Once a Month
_____ Once every 3 Months
_____ Once every 6 Months
_____ Once a Year or Less Frequent

37j. Please indicate the time period of the first meeting that deliberately and explicitly focused on constructability. Place a check below the appropriate period.

Pre-Project Planning			Detail Design/Procurement			Construction		
Early	Middle	Late	Early	Middle	Late	Early	Middle	Late

Yes No

37k. ___ ___ Constructability was an element addressed in this projectís formal written execution plan.

37l. ___ ___ Were the actual cost savings (identified cost savings less implementation cost) due to the constructability program tracked on this project?

If yes, please list? $ _______________

Project Change Management
Completed Project Data: EFA West

Project Change Management Practices

Change Management focuses on recommendations concerning the management and control of both ***scope changes*** and ***project development changes***.

Yes No

41a. ___ ___ Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?

41b. ___ ___ Was a baseline project scope established early in the project and frozen with changes managed against this base?

41c. ___ ___ Were design ìfreezesî established and communicated once designs were complete?

41d. ___ ___ Were areas susceptible to change identified and evaluated for risk during review of the project design basis?

41e. ___ ___ Were changes on this project evaluated against the business drivers and success criteria for the project?

41f. ___ ___ Were all changes required to go through a formal change justification procedure?

41g. ___ ___ Was authorization for change mandatory before implementation?

41h. ___ ___ Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?

41i. ___ ___ Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?

41j. ___ ___ Did the project contract address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract?

41k. ___ ___ Was a tolerance level for changes established and communicated to all project participants?

41l. ___ ___ Were all changes processed through one owner representative?

41m. ___ ___ At project close-out, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?

41n. ___ ___ Was the project organized in a Work Breakdown Structure (WBS) format and quantities assigned to each WBS for control purposes prior to total project budget authorization?

The questionnaire is complete. Thank you for your participation.

Project Change Management
Completed Project Data: EFA West

Project Phase Table

Project Phase	Start/Stop	Typical Activities & Products	Typical Cost Elements
Pre-Project Planning Typical Participants • Owner personnel • Planning Consultants • Constructability Consultant • Alliance/Partner	**Start: Defined Business Need that requires facilities** **Stop: Total Project Budget Authorized**	• Options Analysis • Life-cycle Cost Analysis • Project Execution Plan • Appropriation Submittal Pkg • P&IDs and Site Layout • Project Scoping • Procurement Plan • Arch. Rendering	• Owner Planning team personnel expenses • Consultant fees & expenses • Environmental Permitting costs • Project Manager Construction Manager fees • Licensor Costs
Detail Design Typical Participants: • Owner personnel • Design Contractor • Constructability Expert • Alliance/Partner	**Start: Design Basis** **Stop: Release of all approved drawings and specs for construction (or last package for fast-track)**	• Drawing & spec preparation • Bill of material preparation • Procurement Status • Sequence of operations • Technical Review • Definitive Cost Estimate	• Owner project management personnel • Designer fees • Project Manager Construction Manager fees
Demolition/Abatement (see note below) Typical Participants • Owner personnel • General Contractor • Demolition Contractor • Remediation/Abatement Contractor	**Start: Mobilization for demolition** **Stop: Completion of demolition**	• Remove existing facility or portion of facility to allow construction or renovation to proceed • Perform cleanup or abatement/remediation	• Owner project management personnel • Project Manager Construction Manager fees • General Contractor and or Demolition specialist charges • Abatement/remediation contractor charges

Note: The demolition/abatement phase should be reported when the demolition/abatement work is a separate schedule activity (potentially paralleling the design and procurement phases) in preparation for new construction. Do not use the demolition/abatement phase if the work is integral with modernization or addition activities.

Project Change Management
Completed Project Data: EFA West

Project Phase Table (Cont.)

Project Phase	Start/Stop	Typical Activities & Products	Typical Cost Elements
Procurement Typical Participants • Owner personnel • Design Contractor • Alliance Partner	**Start: Procurement Plan for Engineered Equipment** **Stop: All engineered equipment has been delivered to site**	• Vendor Qualification • Vendor Inquiries • Bid Analysis • Purchasing • Expediting • Engineered Equipment • Transportation • Vendor QA QC	• Owner project management personnel • Project Manager Construction Manager fees • Procurement & Expediting personnel • Engineered Equipment • Transportation • Shop QA QC
Construction Typical Participants • Owner personnel • Design Contractor (Inspection) • Construction Contractor and its subcontractors	**Start: Beginning of continuous substantial construction activity** **Stop: *Mechanical Completion***	• Set up trailers • Site preparation • Procurement of bulks • Issue Subcontracts • Construction plan for Methods Sequencing • Build Facility & Install Engineered Equipment • Complete Punchlist • Demobilize construction equipment • Warehousing	• Owner project management personnel • Project Manager Construction Manager fees • Building permits • Inspection QA QC • Construction labor, equipment & supplies • Bulk materials • Construction equipment • Contractor management personnel • Warranties
Start-up Commissioning Note Does not usually apply to infrastructure or building type projects Typical Participants • Owner personnel • Design Contractor • Construction Contractor • Training Consultant • Equipment Vendors	**Start: *Mechanical Completion*** **Stop: Custody transfer to user/operator (steady state operation)**	• Testing Systems • Training Operators • Documenting Results • Introduce Feedstocks and obtain first Product • Hand-off to user operator • Operating System • Functional Facility • Warranty Work	• Owner project management personnel • Project Manager Construction Manager fees • Consultant fees & expenses • Operator training expenses • Wasted feedstocks • Vendor fees

Appendix B

PRACTICE USE INDEX CALCULATIONS

The summated rating scale, a commonly used tool in survey research, was utilized in the calculation of the practice use indices Each practice use index is based on a scale of zero to ten. Thus, if all practice elements were used to the highest degree the practice index would be a ten, and if no practice elements were used at all the practice index would be a zero. The practice elements are all given equal weights of one. As the database grows, a more sophisticated analysis can be performed in order to assign different weights to each practice element.

In the following example, responses to the practice use elements are shaded. These response values, or scores, are recorded through to the end of each practice section where they are summed to get a total. In order to scale each practice use index to a value between zero and ten, each total is divided by one tenth the number of elements in the practice use section

Team Building Practice Use

Question	Yes	No	Score
36. Was a team building process used for this project?	1.00	0.00	1.00
36a. Was an independent consultant used to facilitate the team building process?	1.00	0.00	0.00
36b. Was a team-building retreat held early in the life of the project?	1.00	0.00	1.00
36c. Did this project have a documented team-building implementation plan?	100	0.00	0.00
36d. Were objectives of the team building process documented and clearly defined?	1.00	0.00	0.00

Question	Regularly	Sometimes	Seldom	Never	Score
36e. Were team building meetings held among team members throughout the project?	1.00	0.67	0.33	0.00	0.33
36f. Were follow-up sessions held to integrate new team members and reinforce concepts?	1.00	0.67	0.33	0.00	0.00

36g. Please indicate the project phases in which team building was used

Pre-Project Planning	Design	Procurement	Construction	Startup	Score
0.30	0.30	0.10	0.20	0.10	0.20

36h. Please indicate the parties involved in the team building process.

Owner	Designer	Contractors	Major Suppliers	Subcontractors	Constr. Mngr.	Other	Score
0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.334

TOTAL	2.86
9 Questions, Maximum Score of 9 ⇒ Divide total by 0.9 to scale to 1-10 point range	
Team Building Practice Use Index	**3.18**

Constructability Practice Use

Question	Yes	No
37. Was Constructability implemented on this project?	X	

37a Which of the following best describes the constructability program designation for this project? (Choose one)	
0.00	No designation
0.25	Part of standard construction management activities
0.50	Part of another program, such as Quality or only identified on a project level
0.75	Recognized on a corporate level, but may be part of another program
1.00	Stand-alone program on same level as Quality or Safety

Score
0.25

37b. Which of the following best describes the constructability training of personnel for this project? (Choose one)	
0.00	None
0.25	If any occurs, done as on-the-job training
0.50	Awareness seminar(s)
0.75	Part of standard orientation
1.00	Part of standard orientation; deeply ingrained in corporate culture

Score
0.25

37c Which of the following best describes the role of the constructability coordinator for this project? (Choose one)	
0.00	Coordinator not identified
0.25	Part-time if identified; very limited responsibility
0.50	Informal full- or part-time position, responsibilities vary
0.75	Formal full- or part-time position; responsibilities vary
1.00	Full-time position, plays major project role

Score
0.50

Continued next page

37d. Which of the following best describes the constructability program documentation for this project? (Choose one)	
0.00	None; CII documents may be available
0.25	Limited reference in any manual; CII documents may be distributed or referenced
0.50	Project-level constructability documents exist, may be included in other corporate documents
0.75	Project constructability manual is available
1.00	Project constructability manual is thorough, widely distributed, and periodically updated

Score
0.00

37e. Which of the following best describes the nature of project-level efforts and inputs concerning constructability for this project? (Choose one)	
0.00	None
0.25	Reactive approach, constrained by review mentality, poor understanding of proactive benefit
0.50	Aware of major benefits, proactive approach
0.75	Proactive approach, routinely consult lessons learned
1.00	Aggressive, proactive approach from beginning of project; routinely consult lessons learned

Score
0.50

37f. Which of the following best describes the implementation of constructability concepts on this project? (Choose one)	
0.00	Very little concept implementation
0.25	Some concepts used periodically; often considered too late to be of use
0.50	Selected concepts applied regularly; full use, timeliness of input varies
0.75	All concepts consistently considered; timely implementation of feasible concepts
1.00	All concepts consistently considered, continuously evaluated, aggressively implemented

Score
0.50

Continued next page

37g. Constructability ideas on this project were collected by: (As many as applicable)	
0.10	Suggestion Box
0.30	Interviews
0.50	Review Meetings
0.20	Questionnaire
0.10	Other Methods

Score
0.30
0.50

37h. To what extent was a computerized constructability database utilized for this project? (Choose one)	
0.00	None
0.33	Minimal
0.67	Moderate
1.00	Extensive

Score
0.33

37i. Please characterize the frequency of the constructability reviews and discussions for this project. (Choose one)	
1.00	Once a Week
0.75	Once a Month
0.50	Once every 3 Months
0.25	Once every 6 Months
0.00	Once a Year or Less Frequent

Score
0.75

Continued next page

37j. Please indicate the time period of the first meeting that deliberately and explicitly focused on constructability. (Choose one)	
1.00	Early Pre-Project Planning
0.90	Middle Pre-Project Planning
0.80	Late Pre-Project Planning
0.70	Early Detail Design/Procurement
0.60	Middle Detail Design/Procurement
0.50	Late Detail Design/Procurement
0.20	Early Construction
0.10	Middle Construction
0.00	Late Construction

Score
0.90

Question	Yes	No	Score
37k. Constructability was an element addressed in this project's formal written execution plan.	**1.00**	0.00	1.00
37l. Were the actual cost savings (identified cost savings less implementation cost) due to the constructability program tracked on this project?	1.00	**0.00**	0.00

TOTAL	5.78
12 Questions, Maximum Score of 12 ⇒ Divide total by 1.2 to scale to 1-10 point range	
Constructability Practice Use Index	**4.82**

Project Change Management Practice Use

Question	Yes	No	Score
41a. Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?	1.00	0.00	1.00
41b. Was a baseline project scope established early in the project and frozen with changes managed against this base?	1.00	0.00	1.00
41c. Were design "freezes" established and communicated once designs were complete?	1.00	0.00	1.00
41d. Were areas susceptible to change identified and evaluated for risk during review of the project design basis?	1.00	0.00	0.00
41e. Were changes on this project evaluated against the business drivers and success criteria for the project?	1.00	0.00	1.00
41f. Were all changes required to go through a formal change justification procedure?	1.00	0.00	1.00
41g. Was authorization for change mandatory before implementation?	1.00	0.00	0.00
41h. Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?	1.00	0.00	1.00
41i. Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?	1.00	0.00	0.00
41j. Did the project contract address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract?	1.00	0.00	1.00
41k. Was a tolerance level for changes established and communicated to all project participants?	1.00	0.00	0.00
41l. Were all changes processed through one owner representative?	1.00	0.00	1.00
41m. At project close-out, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?	1.00	0.00	0.00
41n. Was the project organized in a Work Breakdown Structure (WBS) format and quantities assigned to each WBS for control purposes prior to total project budget authorization?	1.00	0.00	1.00
TOTAL			9.00
14 Questions, Maximum Score of 14 ⇒ Divide total by 1.4 to scale to 1-10 point range			
Project Change Management Practice Use Index			**6.43**

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Vita

Brian Douglas Ciaravino was born in Detroit, Michigan on October 15, 1964. He is the son of Shirley Wyka Johnson and John Joseph Ciaravino. After graduating from Hazel Park High School, Hazel Park, Michigan in 1982, he enlisted in the United States Navy. From 1983 to 1990 he served as a surface nuclear medicine hospital corpsman aboard the aircraft carrier USS Carl Vinson (CVN-70) and as a disaster recovery instructor at Naval Construction Training Center (NCTC), Port Hueneme, California. While serving at NCTC, he attended evening pre-engineering classes at Ventura Community College. In 1990, he was accepted for the Enlisted Commissioning Program and in August he began attending the University of Florida in Gainesville. He received his Bachelor of Science Degree in Electrical Engineering with High Honors and commission as an Ensign in the Civil Engineer Corps in May, 1993. During the following years he served as a construction Detachment Officer in Charge with Naval Mobile Construction Battalion FOUR and as a Project Engineer for the Resident Officer in Charge of Construction in Port Hueneme, California. In August, 1997, he entered the Civil Engineering Graduate School at the University of Texas where he studied Construction Engineering and Project Management.

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