Change Management Best Practice Use in NAVFAC and Other Public Projects

by

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Dedication

This thesis is dedicated to my Lord and Savior Jesus Christ, without whom none of this would have been possible; my talented, intelligent, loving wife Annalynn, who in addition to reading this report countless times has been my best friend and counselor; and to Joelle Elizabeth-Mae my daughter, who arrived only a day before this thesis was completed.

I would also like to thank Dr. Steve Thomas for his advice and counsel during these last three months, Dr. Ed Gibson for his direction and guidance, and Dr. Richard Tucker for his leadership and thought provoking discussions.

Abstract

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The Construction Industry Institute (CII) has identified 11 best practices that have shown significant value in improving performance on construction projects. One of these practices is Project Change Management (PCM.) Extensive research by CII has shown that use of this practice can reduce cost growth and schedule growth.

The purpose of this thesis is to evaluate the use of PCM on construction projects by the Naval Facilities Engineering Command (NAVFAC.) It will then compare and contrast NAVFAC's use of PCM to CII's change management practice use as a whole. Comparisons to change management practice use by other public agencies within CII will be made as well.

There are 14 elements to the project change management practice. This thesis shows which PCM practice elements are being used by NAVFAC, and compares their use to practice use by other public CII companies and other private CII companies. An analysis of NAVFAC projects is completed to show if PCM practice elements have the same impact on cost and schedule for NAVFAC as they do for other CII companies. Conclusions and recommendations are presented based on the results of the analysis.

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CHAPTER 1

Introduction

1.1 PURPOSE

The purpose of this thesis is to evaluate the use of identified change order management best practice elements on construction projects by the Naval Facilities Engineering Command (NAVFAC) and to compare and contrast their use to the Construction Industry Institute's (CII) change management practice use as a whole. Comparisons to change management practice use by other Public Agencies within CII will be made as well.

CII is a research organization with a singular mission: *improving the competitiveness of the North American construction industry.* CII is a unique consortium of leading owners and contractors who have joined together to find better ways of planning and executing capital construction programs (http://construction-institute.org/). It is comprised of approximately 90 member companies and has performed research with 30 of the nation's top research universities.

Over the last 10 years, 11 Best Practices have been identified by CII through research, implementation, and benchmarking. These practices have been determined to improve specific project performance measures, such as cost performance and schedule performance. One such best practice is Project Change Management (PCM) and 14 key elements have been identified within an effective project change management process. The PCM practice elements and performance measures will be discussed in detail in Chapters 2 and 3.

The CII benchmarking and metrics database contains 901 projects from member companies, both owners and contractors. CII member companies are made up of both public and private firms, but the majority of the organizations are private.

This thesis will examine current NAVFAC projects to determine which PCM practice elements are currently used and which are not. In addition, the effectiveness of the PCM practice will be analyzed. The feasibility of using these key PCM practice elements will be discussed, given the rigid nature of federal construction management procedures.

1.2 SCOPE

This thesis will analyze change order management practice use on construction projects in NAVFAC, and compare their use to the change order management practice use of private CII member companies and other public CII agencies within the CII project database. Change order management practice use will be compared to certain CII project performance measures for NAVFAC projects to determine the possible impact on Navy project performance. Since NAVFAC is a member of CII, Navy projects will be pulled from the existing CII benchmarking and metrics (BM&M) database and compared to new data obtained from NAVFAC specifically for this study. This comparison will indicate whether

Navy projects in the CII database are similar to other Navy projects, and will indicate how well they use the identified 14 best practice elements.

1.3 OBJECTIVES

The overall goal of this study is to identify areas where the Navy might be able to improve its construction change management practices. To meet this goal the following objectives have been set.

1. Characterize the Navy's change order management best practice use in regard to the CII member organizations and to other public agencies.
2. Analyze change order performance for NAVFAC projects identified through surveys.
3. Recommend areas where NAVFAC might be able to improve performance, and determine which methods can be used to accomplish this improvement.

1.4 ORGANIZATION OF THESIS

Chapter 2 will discuss the background of change order management within the construction industry, the CII approach to identifying best practices and performance use factors, and give background on current NAVFAC change order management procedures. Chapter 3 will describe the research approach and methodology used in collecting and analyzing the data. Chapter 4 will present the projects and data used in this study. Chapter 5 will explain the analysis of data. Conclusions and recommendations will be presented in Chapter 6.

CHAPTER 2

Background

2.1 Change Orders In The Construction Industry

An extensive review of current literature was conducted prior to beginning this research. Articles, publications, theses, and journals from architectural, construction and engineering organizations, as well as proceedings from professional conferences spanning the past ten years, were searched. Finally, the detailed research by CII on change orders, the impact of change, best practices, and project performance formed the foundation for the majority of this thesis.

2.1.1 Construction Change Orders

Change orders are a well-known part of the construction business. In construction, changes occur on a daily basis on almost every project. Some are changes to the scope of work, others for project development. These changes may change the amount and type of work, the type of material and method of construction, and the amount and type of labor. Poor change management can lead to cost overruns, schedule delays, poor functional designs, and incomplete projects.

Many changes are due to unforeseen conditions, which can range from an unusual subsurface soil type to the discovery of Native American burial grounds. However, a great many changes are preventable and predictable. Examples of avoidable changes are those caused by design omissions, errors in contract documents, and poor scope definition (McCalley 1997).

2.1.2 Impacts of Changes

Owners, designers, and contractors can each cause changes. On any given project one can expect potential changes from each of these participants. This can lead to serious disputes between participants, and many of these disputes wind-up in court. Newspapers, magazines, and periodicals are filled with articles about projects gone bad, incomplete projects, and the resulting major lawsuits. For example, the San Francisco Fillmore Center redevelopment was tied up in disputes nearly four years after it began, in one of the most complex disputes in city history (Rosenbaum 1994). An Australian mining company, Anaconda Ltd., is disputing $54.1million dollars in liquidated damages on their $1.2 billion Murrin mine in western Australia (Weston 2000).

According to the Federal Facilities Council, 50% of change orders stem from errors in the design process. Most of these omissions or revisions are directly related to breakdowns in the interface between design disciplines such as: civil, structural, architectural, electrical, and mechanical. Changes from these errors can account for .2 to .5 percent of the total project costs (Spillinger 2000).

Generally, the impact of change orders is considered to affect the cost and the schedule of a project. One area that is often overlooked is the impact on productivity, which impacts both cost and schedule. Studies have shown that the more changes incurred to the original scope, the higher the loss of productivity and the higher the impact on costs. Studies have shown a direct correlation between the percent loss in productivity and the percent of change orders. They found the resulting cost impact to be substantial (Moselh et. al 1999).

A recent Department of Veteran Affairs study, described at the "1997 Symposium on Federal Facilities Beyond the 1990's: Ensuring Quality in an Era of Limited Resources," quantitatively showed that the VA spent 10% of all Total Project cost on change orders and claims accounting for around $34 million. Real world examples like this have shown that project changes can have a significant effect on project performance related to cost, labor, and schedule (Siegel 1997).

Whether the contract is competitive lump-sum bid or negotiated, such as a guaranteed-maximum price or cost-reimbursable contracts, change order management is important. Most good construction organizations have programs, systems or processes to deal with change orders (McCalley 1997).

2.1.3 Dealing with Change Orders

Methods of dealing with changes can take almost as many forms and directions as there are types of changes. There are many ways to categorize changes; one method is to group them by timing. The phase of the construction process influences the selection of a method to mitigate or control changes. The basic project development phases are Pre-Project Planning, Design, Procurement, Construction, and Start-up. The vast majority of all changes occur in the fourth phase, construction. The construction industry is fragmented and diverse as are techniques and methods for dealing with the change. The following paragraph discusses some methods for dealing with change by phase, discovered during literature review.

Pre-Project Planning Phase

Many scope changes can be eliminated during the planning process before contracts go out for bid or negotiations just by clearly defining the objectives of the project and effectively developing a good design basis. Work by G. E. Gibson at the University of Texas has shown that this phase has the potential to impact project success more than any other phase (Gibson 1994).

Design Phase

An extremely critical phase of the process where the potential for future change orders can be significantly impacted is the design phase. Some methods of improving this process, which are receiving a lot of attention these days, are Functional Analysis Concept Design (FACD), Partnering, and Design-build. One recent study found that FACD was a viable means of reducing change orders and overall construction costs (Stocks et. al 1996).

Partnering involves getting to know and understand the various players in the process and building teamwork and trust. A study introduced at the 1996 Symposium on Federal Policies to Foster Innovation and Improvement in Construction Facilities validated, to an 80% confidence level, that partnering and trust during the design phase can save 15% across the life of the project (Ellefson 1996).

Procurement Phase

Many times scope changes are a result of the bidding process. Incomplete or confusing invitation for bids (IFB) lead contractors to make errors in their proposals. Thorough constructability reviews prior to IFB can help mitigate these errors. In today's environment, businesses are outsourcing more and more services making it even harder to ensure proper reviews are completed.

Construction Phase

A common practice many contractors take is to document everything. There are two reasons for tracking all changes. First, a contractor must be able to show how each change impacts the project's contract cost and the schedule. Without proper documentation, the owner's perception of a contractor may be poor. If the cost growth can be clearly related to changes in work, this problem can be avoided.

Another reason for documenting everything is a more proactive one. By detailing every aspect of the construction process, when presented with a potential out of scope change, the contractor can explain the full consequences of the change and recommend alternatives. The owner can then decide if the requested change is worth the extra time or money (McCalley 1997).

Owners benefit from a good change order management program as well. Most owners expect and demand some degree of control on projects. Keeping the owners informed of how the money is being spent provides that control. This way owners can make informed decisions during the life of the project.

The Veterans Administration (VA) developed one example of this type of system called ProCATS. This system helps the owner document all changes through each phase of the project. ProCATS then provides a platform for publishing lessons learned, which can then be translated into improvements on future projects (Siegel 1997). Contractually required schedule updating and tracking is another method of controlling change, or at least the impact of change on the schedule.

For some organizations, dealing with change orders means shifting responsibility, accountability and the risk from the owner to the contractor or designer. Adding legal clauses to the contract is the preferred method of doing this. However, these techniques tend to focus on assigning blame, or culpability after the fact, rather than reducing the actual cause of the changes. Over-reliance on these types of risk shifting techniques is a by-product of a "win-lose" mentality, vice a "win-win" mentality. However; legal clauses are needed these days to deal with a "litigation happy" society (Mcalley 1997). Important clauses should deal with areas, which are known to be problem spots such as the change order process itself. A good system or process deals with changes before, or as, they occur versus waiting until the end to solve them (McDonald 1998).

2.2 NAVY BACKGROUND

2.2.1 Organization

The Naval Facilities Engineering Command (NAVFAC) is responsible for maintaining the assets of the Naval shore facilities and for administering the Military Construction Program (MILCON). NAVFAC struggles with change orders just as private owners and contractors do. NAVFAC uses more fixed-price/

lump sum, low bid contracts than most private owners, and the potential for numerous change orders during construction is high.

Official MILCON projects are those projects, which are substantially new construction with a projected cost of $300,000 or more. MILCON projects are initiated six to seven years in advance of construction and must be approved by Congress. In addition, other smaller construction contracts, which make up the majority of the construction work on most bases are not subject to congressional approval.

Each geographic region of NAVFAC has an Engineering Field Division (EFD), these are broken down in to Resident Officer in Charge of Construction (ROICC) offices for each base. These offices consist of civilian engineers, inspectors, contracting personnel, and administrators, as well as Navy Civil Engineer Corps officers. The Federal Acquisition Regulations (FAR) and the Navy's contracting manual (P-68) have guidelines and rules for awarding and administering construction contracts (FAR 1999). However, there is a large amount of leeway and judgment given to the respective Officer's in Charge of Construction (OICC) on each base (NAVFAC 1998).

2.2.2 Navy Practices

The federal government term for change orders is "contract modification." The ROICC project engineer must evaluate all requests for modifications and determine their validity. If valid, the project manager will then send a formal request for modification to the EFD explaining why the request is needed, requesting money if required, and listing the Reason code. (The P-68 manual has a list of standard reason codes.) Once approved, the project manager will negotiate the change with the contractor. In addition, most contracts contain a clause, which permits the government to unilaterally modify a contract under extreme cases where it is justified (CECOS 1999).

Individual field offices may have their own set of lessons learned and a checklist of steps to take in order to proactively manage modifications on a project. While there are some formal steps such as those mentioned above, there is no standard list of change management best practices throughout NAVFAC.

The impact of changes in Navy construction is significant. One study of design changes in Navy construction found 292 design changes on 23 projects averaging $12,000/change, resulting in 17 projects being delayed. Omissions and revisions accounted for 81% of those changes. These omissions accounted for 92% of the total cost of changes and averaged 2.8% of the total completed construction costs (Westmoreland 1998). Table 2.1 shows the results of the Westmoreland study.

Table 2.1 Analysis of Design Changes on Navy Projects

Reason	# Changes	% Changes	% Costs	Total costs	Avg cost
Dimension	22	8	3	$116,357	$5,289
Detail	14	5	2	$50,153	$3,582
Interference	17	6	3	$106,895	$6,288
Omission	145	49	37	$1,284,036	$8,855
Revision	94	32	55	$1,792,900	$19,073
	292	100	100	$3,350,341	$43,087

Although the Westmoreland study was limited to one Field Division (Southern), it is probably reasonable to say the impact across NAVFAC is similar. NAVFAC performs $4.3 billion dollars of construction a year. If 2.8% were attributed to change orders that would equate to approximately $120 million dollars.

2.2.3 Navy Definitions and Terms

Understanding the basic definitions and terms used within NAVFAC may shed some light on how the Navy deals with modifications. Here are just a few definitions taken from the Civil Engineer Corps Officers School's *Field Office Student Guide 1999.* A compiled glossary, given in Appendix A, contains a complete list of terms and definitions from the Field Officers Student Guide.

Scope - The extent, range, or intention of work to be performed. Scope can be:

- **Contract Scope**, which is the physical extent of the construction work as described in the general intent and general paragraphs of the specification or as further defined in the contract drawings and specifications.
- **Project Scope**, which is the extent and limitation of a construction program or phases or increments as stated in approved project descriptions and justification sheets. One contract can include more than one project. Likewise, one project may be accomplished under several different contracts.

Contract modification - Any written change in the terms of the contract.

Change order - A written order, unilaterally signed by the Contracting Officer, directing the contractor to make a change that the Changes clause authorizes the Contracting Officer to order without the contractor's consent.

Definitized defined in the glossary (Appendix A), is a standard term in federal contracting and is not standard in the private construction industry.

2.2.4 Policies

Only one-person can authorize a modification in NAVFAC and that person is the Contracting Officer. Project Managers and engineers cannot authorize a modification or bind the government.

Unauthorized actions by Navy personnel lead to *constructive changes* (changes caused by events other than normal preferred methods.) These are another type of preventable change and there are many potential reasons for these constructive changes such as:

- Erroneous contract interpretation.
- Directing a particular manner of performance. Furnishing defective specifications.
- Requiring higher inspection standards or higher quality than specified.
- Failure to disclose technical information.
- Late or defective Government-furnished property.
- Accelerating a contractor by failing to grant time extensions when excusable delays occur.

Out of scope modifications are not allowed unless they are bilateral. If less than $100K, local contracting officers can authorize, and above $100K requires higher-level approval. Normally all modifications must be definitized and funded before execution, unless it adversely effects the government. Only higher-level commands (EFDs) can approve un-definitized mods (CECOS 1999.)

Field Changes are used to document minor variations to plans and specs, that do not affect price or time, and approval authority for these changes varies from office to office. Each proposed contract modification over $25,000 has a government estimate. Every contract modification (other than administrative) must include a statement addressing whether time was/was not required for the change. All contract modifications indicate the reason for which the modification is issued.

2.2.5 Standard Process

How does a modification begin? The NAVFAC modification process is shown below in Figure 2.1 taken from Topic 3.4 "Management of Construction Modifications" in NAVFAC's <u>*Field Operations Student Guide*</u> (CECOS 1999.)

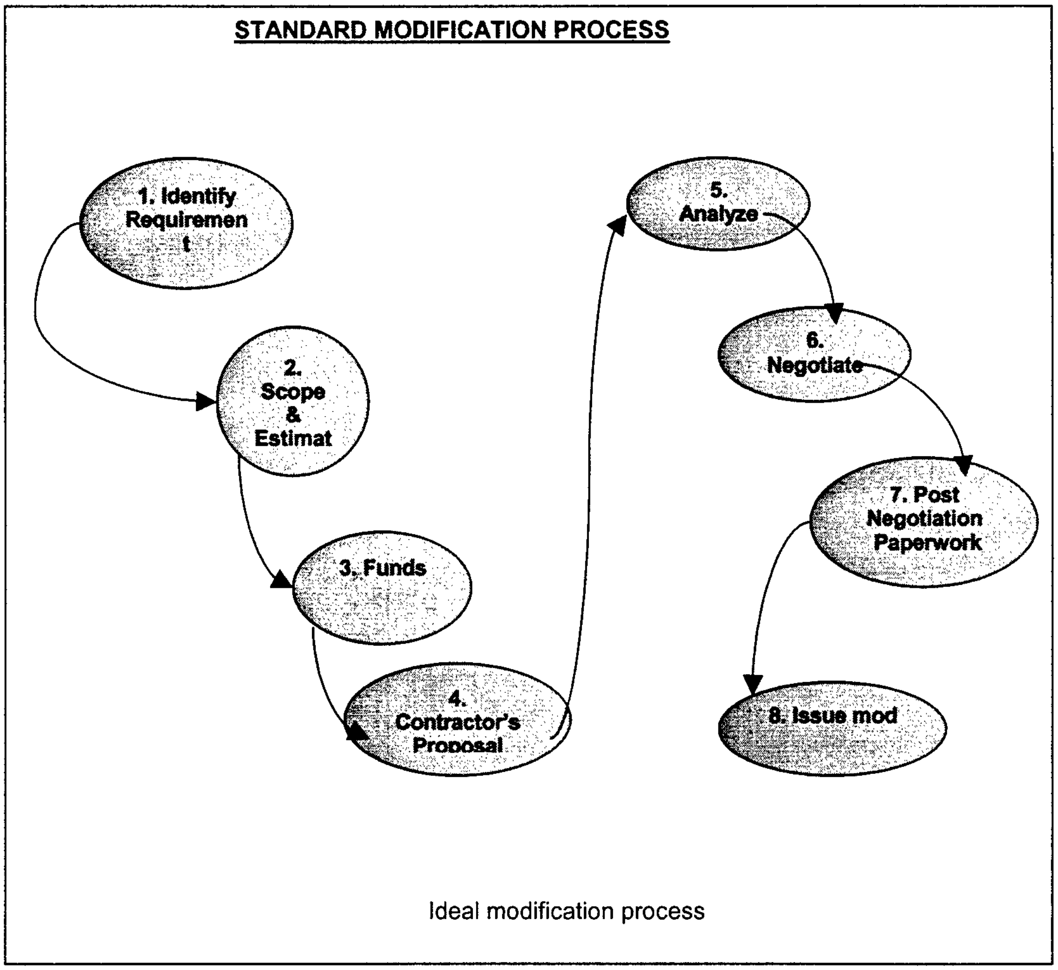


Figure 2.1 Standard Modification Process

The steps illustrated in Figure 2.1 are discussed below.

1. Identify the Requirement

Was the modification Government Initiated or Contractor Initiated?

Action required:

a. Evaluation of proposed change and contract interpretation.

b. Initial contact with Project Manager, Project Engineer.

c. Start Project Change file.

Each potential modification will have its own Project Change (PC) file. This file contains such things as:

- Progress photos.
- Government estimate
- Scope / Justification
- Funds commitment
- Pre- and Post-Negotiation Memorandums and Business Clearances
- Other pertinent information.

d. Read the contract as a whole and listen to the contractor. An issue may have more than one reasonable interpretation. The objective is to arrive at a reasonable interpretation under all circumstances. It is the Contracting Officer's responsibility to be both judge and advocate, but more judge than advocate, such that a fair and impartial decision is made.

2. Develop scope and estimate

This step involves ensuring that all the right people get involved. Preparing the government estimate should include Equitable Adjustments and Secondary Impact or Ripple Costs. The contractor is entitled to an equitable adjustment for both primary and secondary costs.

3. Funding Commitment

An appropriate amount of money must be requested and committed before one can proceed with the modification process.

4. Contractor's Proposal

Once funding is secured, one can send the RFP (request for proposal). Project managers ensure the RFP has been drafted accurately, scopes out exactly what is required, is not used to shop a price from a contractor, and is not issued without full intent to execute a contract modification.

When the proposal is received, a quick review is completed to ensure it addresses the requirements of the RFP, contains enough detail, includes time and money, and is properly certified if required.

5. Analyze the Proposal

A detailed analysis of the proposal considers:

- Technical aspects
- Price and Cost
- Comments from an audit
- Profit analysis

- Time

Pre-negotiation objectives are developed based on the analysis.

6. Negotiate

This step involves preparing the team strategy and expectations, ensuring funds are available prior to negotiating, and the negotiation.

7. Post-Negotiation Paperwork (PNP)

This step requires developing a Post Negotiation Memorandum or completing a business clearance and getting funds to cover the negotiated amount. The PNP requests execution of modification.

8. Issue the Modification

The contracts division prepares the modification also known as a Standard Form (SF) 30. The SF30 is reviewed prior to sending it to the contractor. The Contractor signs the SF30, returns it, and then a Contracting Officer signs the SF30.

2.2.6 Un-definitized Modifications

In unusual circumstances where it is not possible to pre-price a modification due to the character of the changed work, or it is in the best interest of the government (to decrease the cost of delay), an un-definitized maximum priced modification can be used (CECOS 1999). The standard process for an un-definitized modification is shown via flow chart in Appendix B. An un-definitized modification:

· Directs the Contractor to proceed with the work.

· Obligates funds and sets the absolute maximum or not to exceed amount.

· Establishes a definitization schedule.

· Requires that the Government be notified when 50% of the funds obligated have been expended.

The policies and procedures discussed above help provide consistency in processing a change within NAVFAC construction contracting; however, there is plenty of room for interpretation and judgment by individuals. No "best practices" have been identified for the skillful management of project change as a whole. CII has studied PCM in a more comprehensive manner, as outlined in the next section.

2.3 CII BACKGROUND

The Construction Industry Institute, located in Austin, Texas, has contributed a great deal of resources and time to determining which practices can help prevent or reduce the number of change orders in construction. CII has produced hundreds of relevant documents and publications since the late 80's. This section discusses some of the major research publications and source documents leading to the development of CII's current change management best practice.

2.3.1 CII Research

In April of 1990, CII's Strategic Planning Committee implemented a research effort to list areas of project performance, which needed focused improvement, and to discuss recommendations to improve those areas. The resulting publication is *Assessment of Project Management Practices and Performance (RSO-4)*.

This publication RSO-4 looked at 8 Project Management Principals and attempted to correlate the use of these principals with project performance. These principals are listed below:

1) Strategic Project Organization
2) Construction practices
3) Design effectiveness
4) Project controls
5) Quality management.
6) Material management.
7) Human resource management.
8) Safety management.

Data were collected from 428 Companies resulting in 1,902 responses to surveys. Analysis of these responses showed the potential cost benefits of improving the use of the 8 principals to be a 25% gross savings. The corresponding benefit cost ratio of 15:1 implied a potential savings of $15 billion dollars industry-wide. The company responses also showed that owners on average used only 70% of the 8 principals and practices, and that only 2/3 of all projects meet initial objectives. This study helped to prove a clear need for improvement in specific areas. Although PCM was not a separate category in this study it is inherently included within principals 2, 3, and 4. Further CII studies did focus on change (Strategic Planning Committee 1990).

The CII research committee on Project Change published Source Document 66 (SD-66) on *The Impact of Construction Changes & Change-orders* in 1991. The research group reviewed available published literature and concluded that the body of works on change orders in construction could be grouped into three categories: Legal aspects and ramifications of change, management techniques, and analytical models. The majority of these focused on the legal aspects and ramifications. This study also tried to identify specific sources of change orders and their impact.

SD-66 reported that the most common source of change on a project was an alteration or scope change. The management techniques used to reduce project change that were most often mentioned in the accompanying literature review were the use of a work breakdown structure (WBS), a material factor (MF), and forensic scheduling.

This research document helped show the impact of multiple changes on a project such as the loss of momentum, efficiency, and productivity. Impacts of even small changes get magnified as the number of changes increases during project life. The committee recommended that organizations:

1) Ensure the accuracy and completeness of the documents prior to award
2) Thoroughly review constructability

3) Record all work on a WBS and use computer CPM modeling to create valid baselines, and document all work
4) Estimate the potential for change
5) Track project performance, lost time, and other impacts
6) Analyze changes promptly before memory loss, and keep complete files of each
7) Use modern computers to help with these processes

In 1995, the CII commissioned a study to quantify the impacts of project change; the results were published in CII's Source Document 108. CII estimated the impact of changes on the construction industry to be between $13-26 billion dollars. This group analyzed over 90 projects, tested 3 hypotheses, and found reliable quantifiable relationships between the amount and timing of change and their impacts.

Specifically they showed at a 10% statistical level of significance: 1) a limited linear relationship between the amount and timing of changes, 2) the more change, the higher the negative impact on labor productivity, 3) hidden costs increase with project change (Ibbs and Allen 1995).

In another study, the CII Change Management Team published *Quantitative Effects of Project Change, Pub 43*-2, in May of 1995. This report identified the results of a study on 104 owner projects from 35 companies with total installed project costs of $8 billion. This study found a significant correlation between design, engineering, and construction labor productivity and the number of changes. This study also identified the declining ability to recover construction schedules and costs in later stages of projects. The timing of construction start was found to have an impact on the number and size of engineering changes, but no impact on construction changes.

Specific findings showed that projects with less than 6% change experienced better than planned productivity, while those with 25% or more change were all worse than expected. Design-build projects in this study experienced less change than did traditional design-bid-build.

Project managers, interviewed in this study did consider the impact of individual changes before implementation; however, few considered the cumulative impact of multiple small changes over the life of a project. The data show that projects cannot endure numerous changes without a resulting decline in cost performance (The Change Management Team 1995).

2.3.2 Change Management Practices

The large of amount of research and published findings from CII identified potential savings and impacts of change management along with recommendations, which led to the development of CII's Special Publication 43-1, *Project Change Management*, in 1995.

Special Publication 43-1 was based on all the previous research focused on developing an effective change management system and outlined identified best practice elements for each phase of the project life cycle (Project Change Management Research Team 1995).

First, the CII Research team developed the following fundamentals of effective change management:

- Develop a balanced change culture
- Recognize change
- Evaluate change
- Implement change
- Continuously improve from lessons learned

Next they presented elements of each construction phase and listed best practices for each phase. Prior to pre-project planning, during business planning, an early baseline scope must be established and institutional controls created, which allow for quantification of the downstream impacts. Some of the best practice issues listed for each stage were:

Pre-Project Planning stage

Clearly develop scope, schedule, and costs and ensure they meet business objectives. Develop a change management plan, process, and procedures. Establish a tolerance level for change. Consider unknowns and potential changes along with areas of uncertainty and their associated risks.

Design stage

Create a formal value engineering team. Freeze scope changes and manage change against the baseline. Ensure good communication of the baseline.

Procurement

Specify in the contract the criteria for change and who is authorized to request and approve of changes. Require change documentation in the contract.

Construction Phase

Utilize a checklist and analyze and review issues for any impact to the plan. Implement the change process early and communicate it early to all parties. Authorize beneficial changes early and do so promptly. Effectively collect and share lessons learned.

2.3.3 The Benchmarking and Metrics Committee (BM&M)

The BM&M committee was formed by CII in late 1993 with the purpose of collecting and analyzing continuous data. The committee is comprised of approximately 20 representatives from member companies. The committee's goal is to capture metrics on the "critical few" areas of highest concern to the customers. In this case, the customers are the senior members of the companies, which make up the membership of the CII. Their intent is to quantify the benefits of implementing best practices over-time (Hudson 1997).

In addition to the constraint of customer satisfaction, these metrics had to meet constraints determined by the committee such as:

- Important
- Do-able
- Universally applicable
- Willingness to share data for metrics

The commonly agreed upon performance areas are pre-project planning, budget, schedule, safety, team building, constructability and change management (Hudson 1997). Metrics for each area were determined and questions were created to measure each metric and the first surveys of questions went to CII member companies in 1996 and 1997.

The 14 best practice elements for effective change management identified by the committee for use in the benchmarking survey were:

1) Active use of a formal documented change management process familiar to each participant.
2) Establishment of a baseline project scope early on, and all future changes managed against this base.
3) Establishment of design freezes once designs are complete, and communication of these freezes.
4) Identification of areas susceptible to change and evaluation of risk during the design phase.
5) Evaluation of all changes against the business drivers and success criteria for the project.
6) Requirement of a formal change justification procedure.
7) Required authorization for change prior to implementation.
8) Use of a system to ensure timely communication of change information to all participants and disciplines.
9) Proactive measures by project personnel to promptly settle, authorize, and execute change orders.
10) Better use of contractual clauses, which address change classification, personnel authorized to request and approve changes, and the basis for adjusting the contract.

11) Establishment and communication of a tolerance level for changes.

12) Use of one owner representative to process changes.

13) Evaluation at closeout of all changes and their impact on actual cost and schedule performance.

14) Use of the Work Breakdown Structure (WBS) for quantities and control purposes prior to project authorization.

These practice elements have been shown to have a positive impact on cost improvement. While other practices and techniques may have a beneficial impact on cost and schedule, the rest of this thesis focuses on these 14 practice elements.

CHAPTER 3

Research Methodology

This chapter outlines the methods used to perform the analysis presented in this thesis. Techniques used to analyze the data are also presented. It also contains a discussion of the metric formulas and definitions used in this thesis.

Figure 3.1 illustrates the methodology used in developing this thesis.

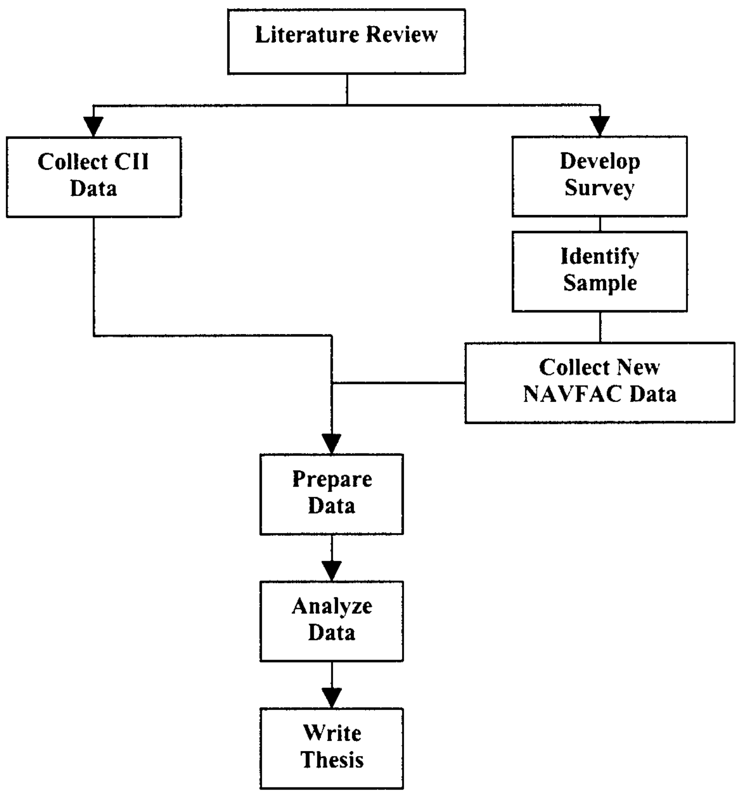


Figure 3.1 Methodology Flowchart

3.1 Literature Review

An extensive literature review was performed as discussed in Chapter 2. The information obtained in the review was used to plan the study, develop research questions and the survey methodology.

3.2. Data Gathering

Most of the data used to draw the conclusions and make recommendations came from the 1999 CII Benchmarking and Metrics database. Permission to access and use CII data and information for this study was requested and granted prior to start. CII has collected change management practice use data from member companies since 1998, and has collected performance data since 1996. Information covered in this thesis covers projects from 1996 to 2000.

Additionally, new project data from current Navy project managers at NAVFAC was solicited and received as well. A survey for new NAVFAC projects was developed and patterned after existing CII benchmarking and metrics surveys. Respondents were selected by identifying officers in ROICC offices at each of the EFDs, which are spread out geographically. The surveys were sent and data collected for new NAVFAC projects.

NAVFAC is a member of CII and as such has provided projects that are included in the CII database. Comparisons between the CII BM&M project database and the new NAVFAC data will enable measurement of project change management practice use. The new NAVFAC data were compared to and then grouped with these older CII NAVFAC projects. The combined Navy projects were compared to CII companies as a whole, and then compared to other public agency projects within CII.

3.2.1 CII Benchmarking and Metrics Survey Data

The data used from the CII BM&M database was collected from annual surveys to the 90 member companies of CII. The survey is distributed, filled out and returned electronically. This survey, an extract is provided in Appendix C, consists of 3 divisions. The first section deals with instructions and respondent information, the second deals with quantitative project information, and the third is actual practice usage.

For this study, only portions of the survey questions were used. Questions 1-12 ask for project and point of contact specific administrative information. Questions 13-14 ask for budget and schedule numbers by project phase. Question 15 deals with the number and cost of project development and scope changes. Questions 41a-41n deal with PCM practices, which is the most relevant section for this thesis.

3.2.2 NAVFAC Survey Data

Although NAVFAC is a member company of CII, the number of NAVFAC projects in the 1999 BM&M database was quite small (only 20 projects). In order to analyze enough Navy projects to be statistically significant, more Navy projects were needed. This was accomplished by sending out the "Analysis of NAVFAC" survey, which is a smaller version of the CII BM&M

survey. The "Analysis of NAVFAC" survey was developed using appropriate questions from the existing CII BM&M survey.

The survey, which is shown as Appendix D, focused on the 14 PCM practice elements. The first few questions (1-6) asked for point of contact and administrative information. The next questions (7-8) ask for information about the project nature and project type. Project type is the broad industry sector such as: building, industrial, or infrastructure. Project nature includes grass roots, modernization, or add-on. These are defined below:

- 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 (add-on) - a new addition that ties in to an existing facility, often intended to expand capacity

The next section of the survey asked for budgeted and actual costs by phase. The phases are described in Appendix D. Section 2 asked for the projected and actual schedule dates by phase, and the actual number and cost of project development and scope changes. Finally, the survey asked which of the 14 change management practice elements were used. Response to these questions was indicated by a yes/no mark placed on the electronic survey.

Emails were sent to 40 NAVFAC Engineering Field Divisions and ROICC offices requesting volunteers for this survey. Thirty-five officers volunteered to fill out the survey and submit data. These officers represented each of the 4 major Field Divisions: Atlantic, Southern, Southwest and Pacific. Data collection began in March of 2000 and ended in June of 2000. A total of 15 surveys were returned from the selected sample. The results of this survey and the CII data are presented in the next Chapter.

3.3 ANALYSIS METHODS

This section contains a discussion of the metric formulas and definitions used in this thesis. Standard CII language and definitions are used throughout this thesis. There are five basic performance areas mentioned in the literature review; this thesis focuses on three of them. The three basic performance metrics evaluated from the CII *1999 Benchmarking and Metrics Report* are Cost, Schedule, and Changes (CII 1999). Each Performance Metric has several performance factors described below and were calculated for each sample project.

3.3.1 Cost Performance Factors

The factors used in the Cost Performance category are:

1. **Project Cost Growth**. Formula:
$$\frac{\text{(Actual total Project Cost} - \text{Initial Predicted Project Costs)}}{\text{Initial Predicted Project Costs}}$$
2. **Project Budget Factor**. Formula:
$$\frac{\text{Actual Total Project Costs}}{\text{Initial Predicted Project Costs + Approved Changes}}$$
3. **Phase Cost Factor**: Formula:

$$\frac{\text{Actual Phase Cost}}{\text{Actual Total Project Costs}}$$

There is a Phase Cost Factor for each project phase.

4. **Phase Cost Growth**:
Formula: $$\frac{\text{(Actual phase cost- Initial predicted cost)}}{\text{Initial predicted phase costs.}}$$

There is a Phase Cost growth factor for each project phase.

3.3.2 Schedule Performance Factors

1. **Project schedule growth**: Formula:

$$\frac{\text{(Actual total project duration – Initial predicted project duration)}}{\text{Initial predicted project duration}}$$

2. **Project Schedule Factor:** Formula:

$$\frac{\text{Actual total project duration}}{\text{Initial predicted project duration + approved changes}}$$

3. **Phase Duration Factor**: One for each phase. Formula:

$$\frac{\text{Actual Phase Duration}}{\text{Actual Overall Project Duration}}$$

4. **Total Project Duration** in weeks.

5. **Construction Phase Duration** in weeks.

3.3.3 Change Performance Factors

Change Cost Factor is the measure of the cost of changes as a percentage of the total project cost. Formula:

$$\frac{\text{Total Cost of Changes}}{\text{Actual Total Project Cost}}$$

The CII database contains these calculated performance metrics and practice use index scores for six practices. In this thesis the PCM practice is of primary concern. For privacy reasons CII raw data are not publicly available. Raw data taken from the 15 "Analysis of NAVFAC" surveys representing new Navy projects were input into a spreadsheet program and each performance factor calculated. These data are presented and discussed in Chapter 4.

3.3.4 PCM Practice Use Index

A summary rating scale was utilized to calculate the practice use index for PCM from the answers to the "Analysis of NAVFAC Surveys". This rating scale methodology is commonly used in survey research. The change management practice use index scale is based on a scale from zero to ten with each question uniformly weighted. Thus if one of the 14 best practice use questions is answered "yes" a value of 1 is given. Likewise, if "no" was marked a 0 is given. The answers are summed and divided by 1.4 to place them on a 10-point scale. If all 14 questions were answered yes, the result is a raw score of 14, which when divided by 1.4 equals 10. A sample survey is demonstrated in Table 3.1. In this example the project's raw score is 10, which provides a practice use index of 7.14.

Table 3.1 Change Management Practices

Project Change Management Practices	Yes	No	Score
1. Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?	1.0		1
2. Was a baseline project scope established early in the project and frozen with changes managed against this base?	1.0		1
3. Were design "freezes" established and communicated once designs were complete?	1.0		1
4. Were areas susceptible to change identified and evaluated for risk during review of the project design basis?		0.0	0
5. Were changes on this project evaluated against the business drivers and success criteria for the project?	1.0		1
6. Were all changes required to go through a formal change justification procedure?	1.0		1
7. Was authorization for change mandatory before implementation?	1.0		1
8. Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?	1.0		1
9. Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?	1.0		1
10. Did the project contract address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract?	1.0		1
11. Was a tolerance level for changes established and communicated to all project participants?		0.0	0
12. Were all changes processed through one owner representative?	1.0		1
13. At project closeout, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?		0.0	0
14. 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?		0.0	0
	Raw score		10
	Index Score	10/1.4	**7.1 4**

CHAPTER 4.0

Data Presentation

This chapter is organized into 2 sections. The first gives the demographic distribution of the CII BM&M database. The second presents change order performance in the NAVFAC projects.

4.1 CII BENCHMARKING AND METRICS DATABASE

CII data is gathered annually for each of the five project performance areas and the six practice-use areas, which were discussed in Chapter 2. However, this research investigation has concentrated on the Project Change Management practices relative to the Navy and how their use impacts performance metrics such as cost, schedule, and change performance.

The CII database contains Owner and Contractor project data from public and private organizations, and from both domestic and international projects. Currently, CII has over 900 construction projects with a total installed cost, of $49.5 billion making it the largest public construction industry project database in the world. The database contains 424 contractor and 477 Owner projects; 333 Owner projects were domestic and 144 of them were international. This thesis only uses the Owner data, because it focused on NAVFAC and owner-specific practices.

The analysis compares project data from the following groups within the CII owner's database: private (Other) CII owners, other public owner projects (non-Navy), and NAVFAC projects. Table 4.1 shows the sample sizes of each dataset.

Table 4.1 Sample size of Data Sets

Data Set	Totals
CII	477
Public	115
Other CII	362
Other public	80
NAVFAC	35

The next section will show the sample distribution graphically.

4.1.1 CII Database Projects

Each dataset can be broken down into groups by industry, size (costs) and nature. The industry groups are classified as buildings, infrastructure, or industrial. Figure 4.1 shows the actual percentage of CII projects in each industry group.

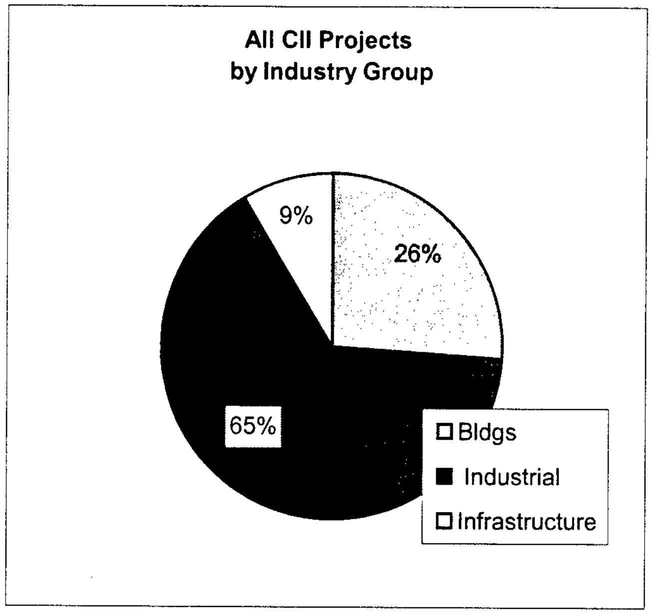


Figure 4.1 CII Database by Industry Group

Projects sizes are less than $15M, $15-50M, $50-100M, and greater than $100M. Figure 4.2 shows CII projects by size. Approximately 50 percent of projects are less than $15M. Approximately 25 percent of all projects are between $15 and $50M.

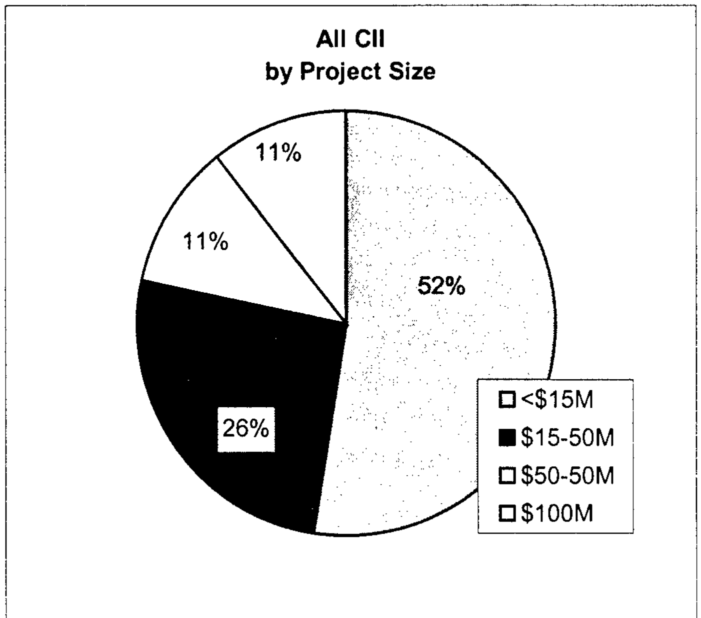


Figure 4.2 CII Database by Nature

The project nature is either grass roots, modernization, or add-on, as defined earlier in Chapter 3. Figure 4.3 shows all CII projects grouped by nature. Grass roots projects account for 33 percent of all projects while Modernization accounts for 40 percent. CII trends indicate a growth towards more modernization projects (BM&M Report 1999).

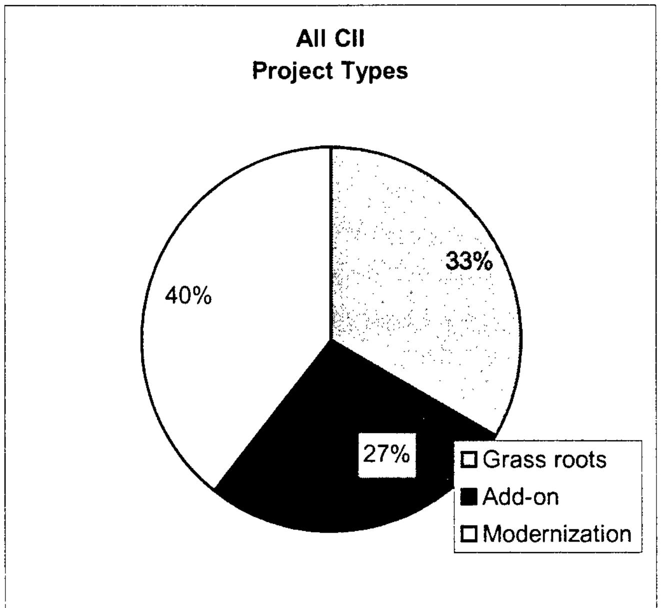


Figure 4.3 CII Database by Project Nature

4.1.2 CII Public Projects

Data from public projects within the CII database, including NAVFAC, include 115 projects from 5 different owners. These owners are NAVFAC, NASA, the U.S. Department of State, the U.S. Army Corp of Engineers, the University of Texas System, and the Tennessee Valley Authority. These projects can be broken down into industry groups, as shown in Figure 4.4. The sample other public includes 60 building, 14 industrial, and 6 infrastructure projects.

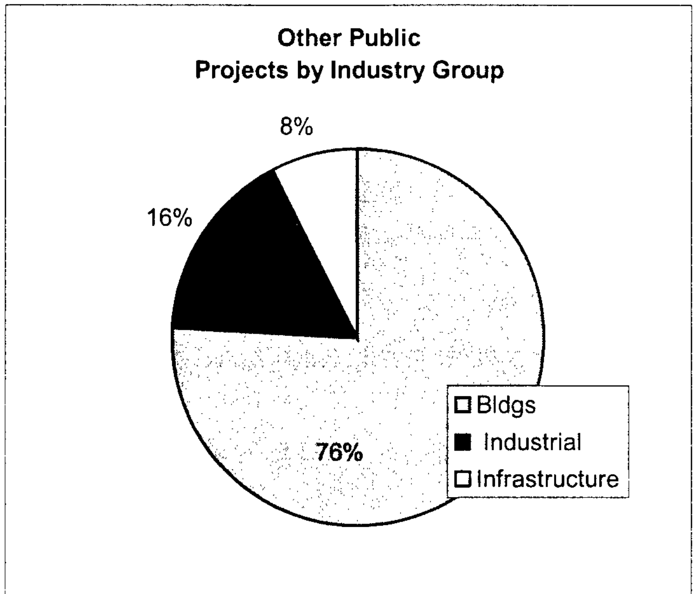


Figure 4.4 Public Agency Projects by Industry Group

Additionally, these projects can be classified by project nature. Twenty-eight are grass roots construction, 42 are modernization, and 10 are add-on projects as shown in Figure 4.5.

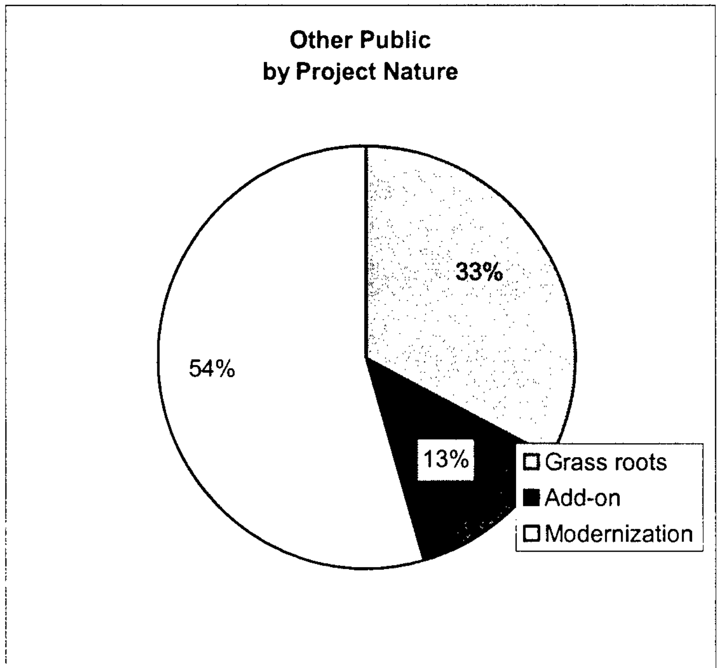


Figure 4.5 Public Projects by Nature of Project

The sample project size is distributed as follows: 58 less than \$15M, 14 are from \$15-50M, eight are from \$50-100M, and none are greater than \$100M as shown in Figure 4.6.

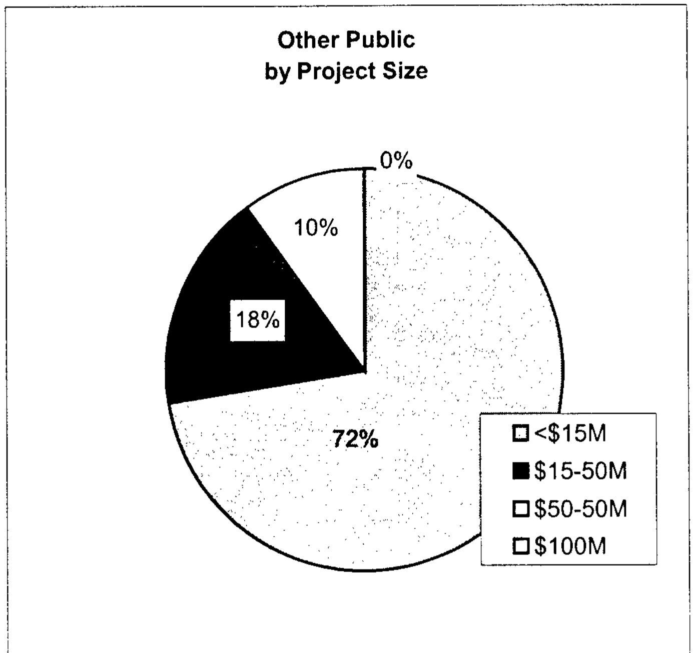


Figure 4.6 Public Projects by Size

4.1.3 NAVFAC Projects

As described earlier in Chapter 3 a NAVFAC project survey was created, distributed, and sample projects collected. In all, 15 surveys were returned. (Note that five more were returned after the analysis was complete and were not included in these results). These included 5 grass roots, 6 modernization, and 4 add-on projects. All of these projects were in the building industry group except for 2 infrastructure and 1 industrial. These new Navy sample projects included 13 projects less than $15M, one between $15-50M, and one over $100M. Overall these distributions were in line with the Navy projects already in the CII database and are included in the figures that follow.

The 20 original NAVFAC projects in the database plus the 15 additional new NAVFAC surveys provides for a sample of 35 projects. A closer look at the 35 NAVFAC projects reveals that they can be broken down into similar categories. The industry groups represented are buildings (28), industrial (3), and infrastructure (4) as shown in Figure 4.7.

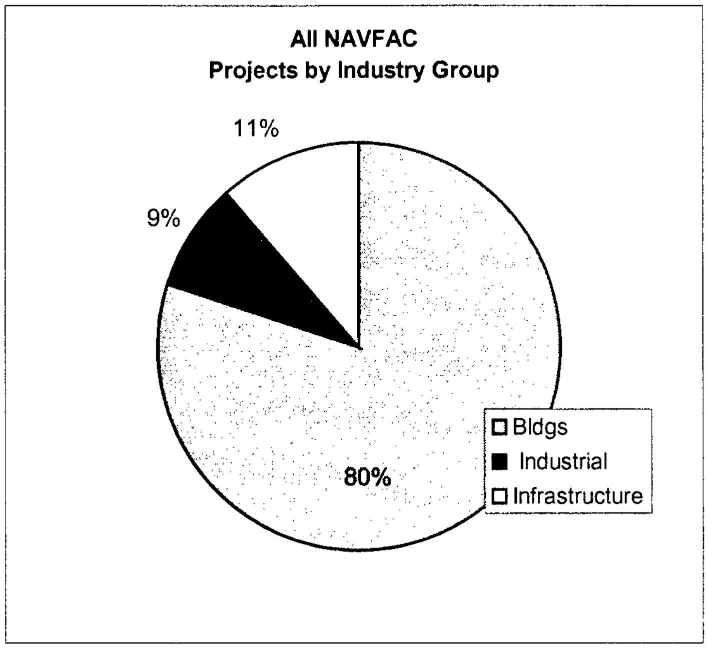


Figure 4.7 NAVFAC Projects by Industry group (n=35)

Grass roots projects account for 21 projects, eight are modernization, and six are add-on as shown in Figure 4.8. For NAVFAC, grass roots projects rather than modernization projects represent the majority of all projects; this is different from the CII data set where modernization projects represent the majority.

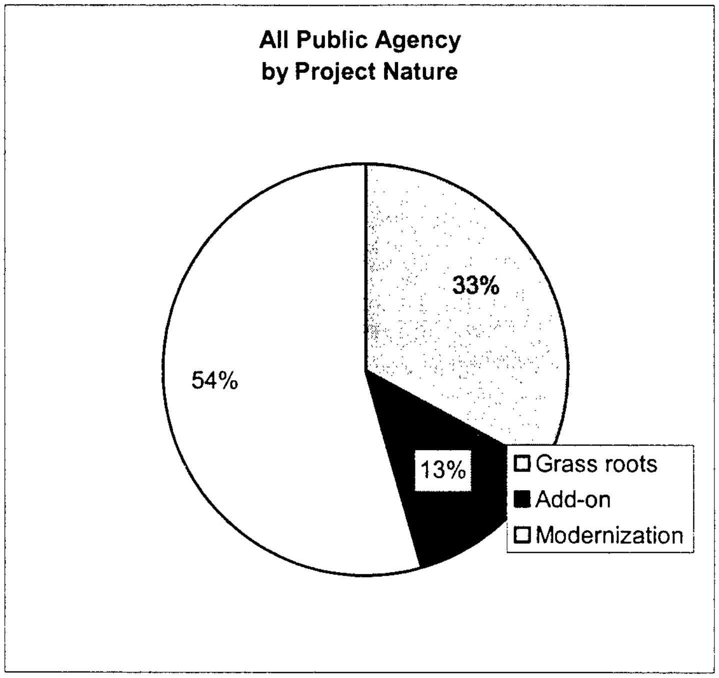


Figure 4.8 NAVFAC by Project Nature (n=35)

The total cost of NAVFAC projects is distributed as follows: 28 less than \$15M, four from \$15-50M, one from \$50-100M and two over \$100M as shown in Figure 4.9. Due to the small numbers of projects in most of these categories, the Navy data will not be stratified into every specific group for comparison. Instead, the largest groups will be examined and compared to CII and other public projects with in the database.

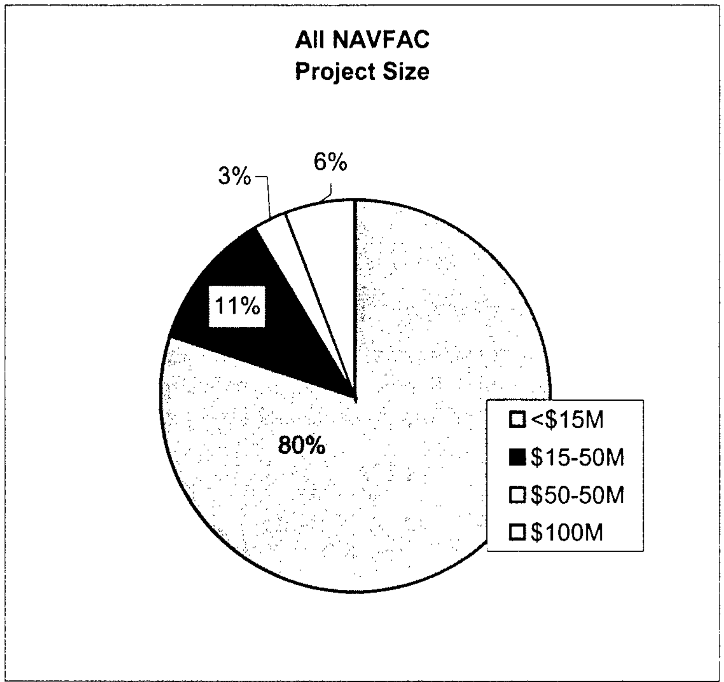


Figure 4.9 NAVFAC by Size (n=35)

4.1.4 Comparisons

To better illustrate the distributions of the data, bar charts, separated into categories for other CII, other public, and NAVFAC, were created and are presented below in Figures 4.10, 4.11, and 4.12 by industry group, nature, and size respectively. Public and Navy projects were removed from the total CII owner sample, and Navy projects were removed from the public numbers.

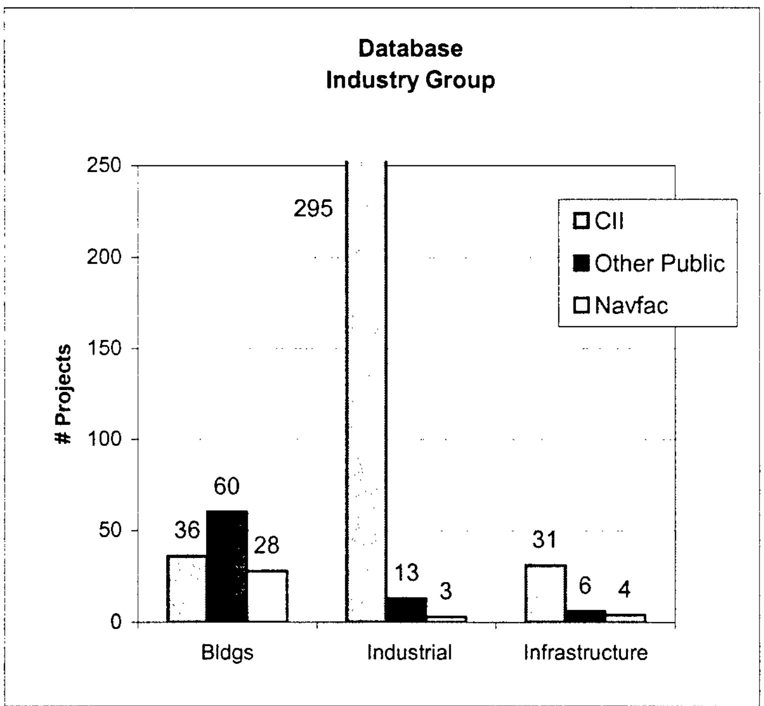


Figure 4.10 Comparisons by Industry group (n-477)

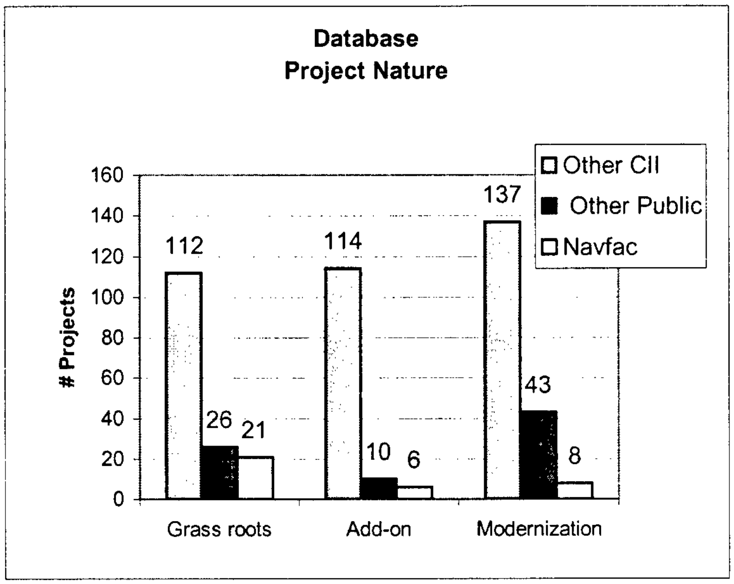


Figure 4.11 Comparisons by Nature (n=477)

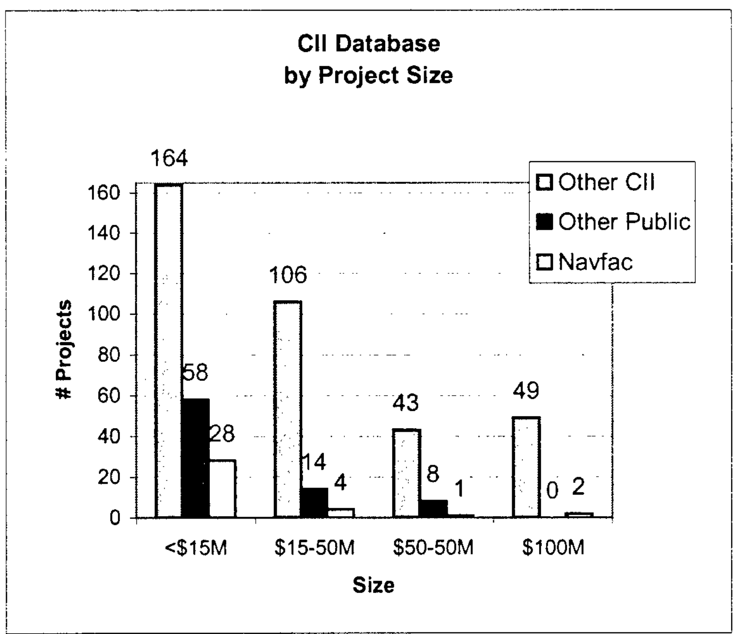


Figure 4.12 Comparison by Size(n=477)

$39 M and 662 weeks of negative schedule growth. There were a total of 544 scope changes accounting for $48 M and 319 weeks of the schedule growth.

Table 4.3 NAVFAC Cost of Changes (n=35)

Cost of Changes	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	Net Schedule Impact of Scope Changes
			($)	($)	(weeks)	(weeks)
Totals	**440**	**544**	**$39,362,985**	**$48,231,938**	**(662)**	**319**

Scope changes accounted for 55 percent of all changes, 55 percent of the cost of changes, and only 33 percent of the schedule impacts. Project development changes, which are in-scope changes, accounted for 45percent of all changes, 45 percent of the cost of changes, and 66 percent of the schedule impact due to changes. Clearly these project development changes have a bigger per change impact than scope changes alone.

Together both types of changes account for 11 percent of the $767 M total cost of all NAVFAC projects surveyed. While the combined effect of data sets indicate that the development changes produced a net reduction in duration (weeks), the scope changes represent an additional 319 weeks in project duration. This is a significant amount of change. If some of the unnecessary changes can be reduced or if the impact of changes can be reduced, NAVFAC stands to benefit substantially.

Overall, the sub samples of public and Navy projects appear similar to the CII database as a whole, with the exceptions noted earlier.

4.2 NAVFAC Change Order Performance

NAVFAC's change order performance is presented in Table 4.2. The NAVFAC projects have a $761 M budget plus $35 M in contingency. Actual completed costs were $767 M in Table 4.2.

Table 4.2 NAVFAC Project size (n=35)

Project Phase	Phase Budget (Including Contingency)	Amount of Contingency in Budget	Actual Phase Cost
Pre-Project Planning	$2,133,237	$38,456	$3,058,682
Detail Design	$31,566,415	$499,120	$37,466,197
Procurement	$10,648,449	$237,349	$5,394,447
Demolition/Abatement	$7,175,403	$784,503	$41,468,674
Construction	$706,699,072	$3,529,306	$5,508,872
Totals	$761,564,077	$35,088,734	$767,700,499

One $100M NAVFAC project experienced several large reductions in scope resulting in savings of over $30M. For the NAVFAC project sample, Table 4.2 shows the actual number of change orders and their impact on cost and schedule. There were a total of 404 project development changes accounting for

CHAPTER 5

Analysis of Data

5.0 ANALYSIS

This chapter describes the procedures used to analyze the presented data. Although mentioned previously, it is worth reiterating that this collection of projects may not be representative of the industry or the Navy at large.

5.1 NAVFAC DATA

Because two different surveys were used to collect NAVFAC data, the first step taken was to check each sample for differences. There are 20 CII NAVFAC projects, and 15 New NAVFAC projects; therefore, a t-test was chosen to test for differences. The null hypothesis states that any differences in these two data sets are that caused by normal sampling error (Type I) and not due to differences in the populations at large (Deikhoff 1996). The descriptive statistics revealed that the variances, for the metric change index, were almost equal so a two-sample t-test with equal variances was used. The results of this test are shown below in Table 5.1.

Table 5.1 t-test New vs. old NAVFAC Data

t-Test: Two-Sample Assuming Equal Variances		
CHANGE INDEX VALUES	**CII Navy**	**New Navy**
Mean	6.46	7.299
Variance	2.510	2.380
Observations	20	15
Pooled Variance	2.455	
Hypothesized Mean Difference	0	
df	33	
t Stat	-1.567	
P(T<=t) one-tail	0.063	
t Critical one-tail	1.696	
P(T<=t) two-tail	**0.126**	
t Critical two-tail	**2.034**	

The results using a two-tailed distribution indicate that the t value = -1.56 is less than t-critical 2.03 and greater than -2.03 assuming a 95% confidence interval. This indicates that there is insufficient evidence to reject the null hypothesis; therefore, any error is treated as non-significant and the null hypothesis is accepted. Based on this knowledge the two data sets were combined into one data set for all NAVFAC Projects.

5.1.2 NAVFAC Performance Factors

Metrics for each new NAVFAC project were calculated for each of the performance factors and PCM elements discussed in Chapter 3. Some projects were returned with missing or incomplete data. While many of these ommissions were corrected via follow up phone-calls or emails, some still exist. The project data that were not corrected were excluded from certain performance metric calculations. The number of cases where this occurred was quite small and did not significantly affect the sample size. For this reason in some specific cases project data and graphs may not sum up to the overall number of cases in the database.

5.1.3 NAVFAC Metrics

Average NAVFAC values for several important metrics broken down by size, nature, and industry group are shown below in Table 5.2. A distribution of all the NAVFAC performance factors, for which data was returned, is shown in Appendix E.

The metrics of greatest value to this study are shown in Table 5.2 starting with column 3 is the change index, the change cost factor, cost growth, and schedule growth.

Table 5.2 Average NAVFAC Performance Metric Values

Size	n	chgindex	costfact	costgrow	schdgrow
<$15M	**28**	7.00	0.08	0.03	-82.90
$15-50M	**4**	6.42	0.14	-0.18	-194.27
$50-100M	**1**	5.71	0.04	0.04	1.71
>$100M	**2**	5.58	0.13	0.08	0.007
Nature		chgindex	costfact	costgrow	schdgrow
Add-on	**6**	7.72	0.05	0.00	0.03
Grass roots	**21**	6.61	0.09	0.02	-116.38
Modernization	**9**	6.68	0.13	0.00	-85.48
Industry Group		chgindex	costfact	costgrow	schdgrow
Bldgs	**28**	6.64	0.08	0.01	-110.88
Hvy Ind	**3**	6.06	0.04	-0.05	2.47
Infrastructure	**4**	8.67	0.26	0.07	0.12

The change management practice use index is of primary concern and will be examined in more detail in the next section. The intent is to compare the change index value of NAVFAC projects to those of other public CII and other private CII projects. The average NAVFAC change index value is 6.81, and the median value is 6.92 with a standard deviation of 1.6. The change index value (7.0) for projects less than $15M, which makes up 52% of all Navy projects, is higher than the overall average.

Infrastructure and add-on projects, which make up 11% and 17% of their respective groups, also had change index values higher than the average. These findings were expected because: although the sample size for these two categories is low, all the infrastructure and add-on projects in this data set were less than $15M in size, and the data shows that projects of less than $15M have higher index scores.

The next few figures are "Box and Whisker Plots", which graphically show change index values grouped by industry, project nature, and size. Figure 5.1 explains how to interpret a box and whisker plot.

Figure 5.1 "Box and Whisker" Plot

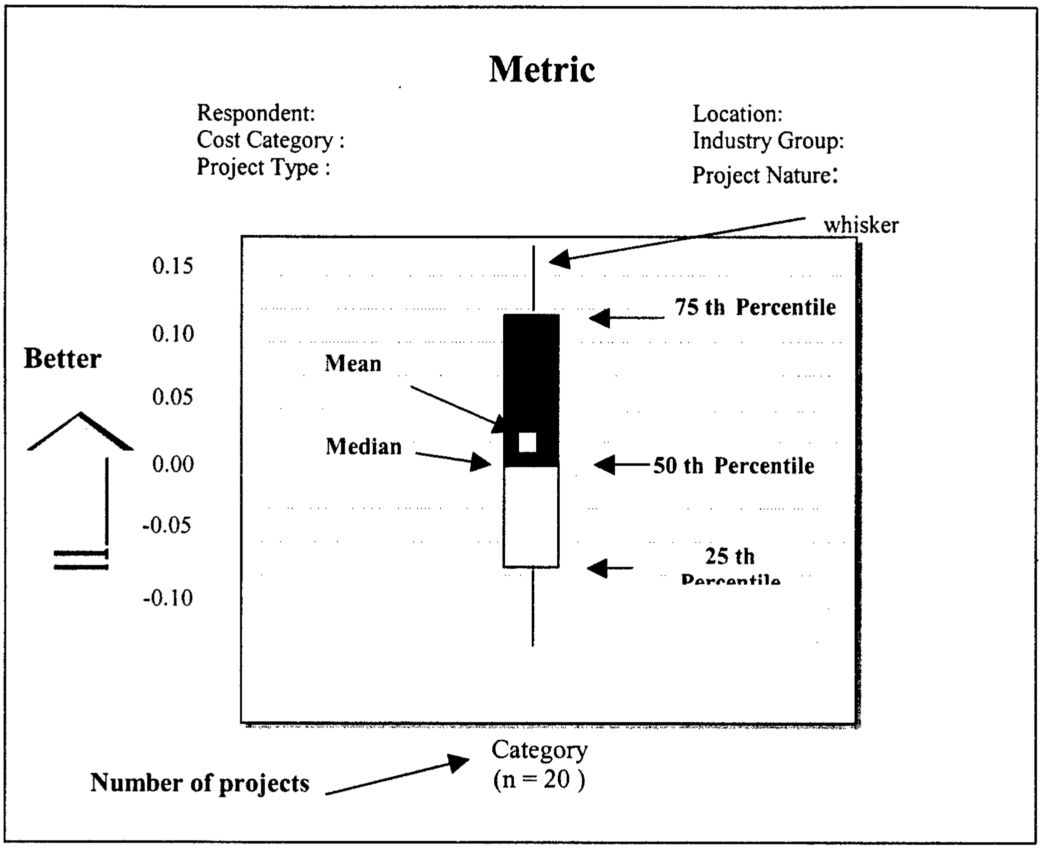


Figure 5.2 shows a box and whisker plot for change index values by industry group for NAVFAC projects.

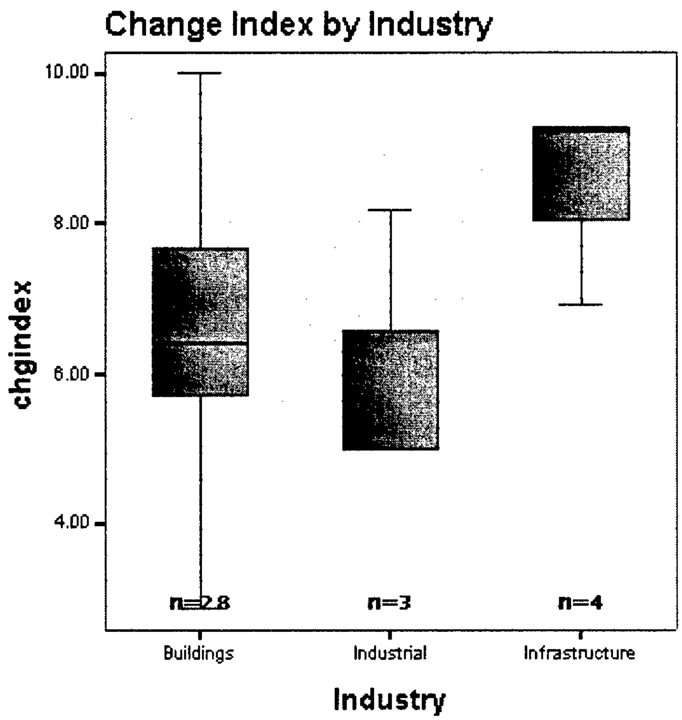


Figure 5.2 Box and whisker plot for NAVFAC by Industry

One observation from this figure is that there is a wide variation in the change practice index for the sample, particularly for grass roots. NAVFAC infrastructure projects in this study have a higher change index score than do buildings, however, the sample size (4) is so small that the significance of this number is questionable. Further study should be accomplished with larger sample sizes to examine each industry group with in NAVFAC.

Figure 5.2 shows a box and whisker plot for NAVFAC grouped by project nature.

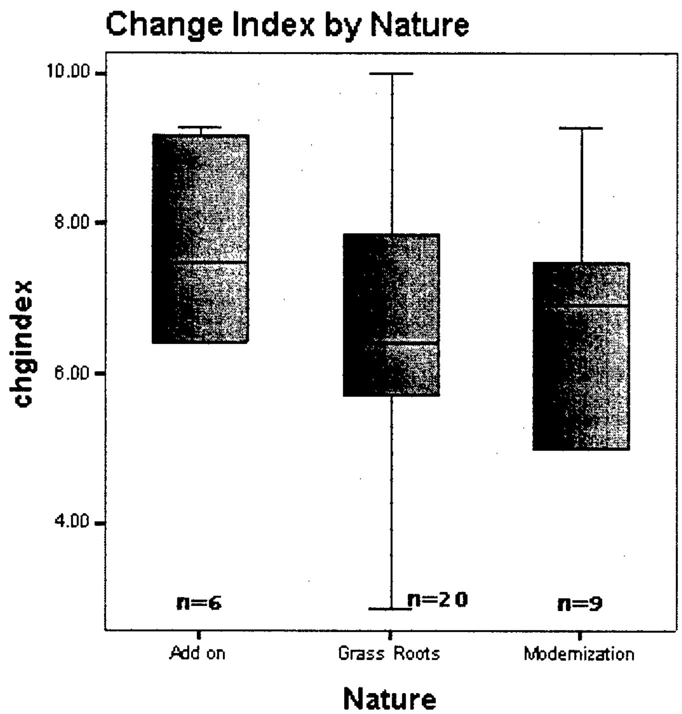


Figure 5.2 Change Index values for NAVFAC grouped by Nature

Figure 5.3 illustrates that projects less than $15M, which represent the majority of the projects in this sample, have much less variance and a smaller inner-quartile range than those $15-50M (sample sizes are low so the significance of this is as well). As shown there are not enough projects over $50M in size to compare.

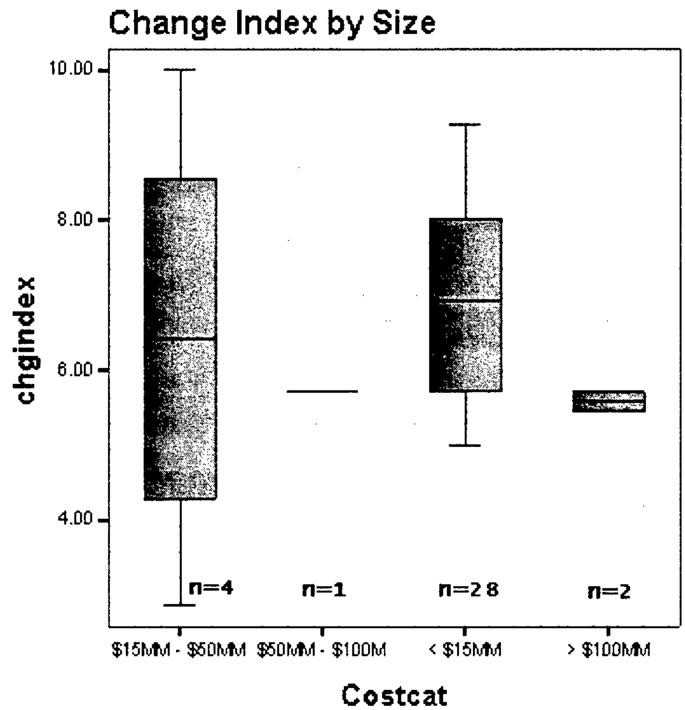


Figure 5.3 Box and Whisker of Change Index by size

5.2 OTHER PUBLIC DATA

The next test is to compare all NAVFAC projects to the data set of other public projects. There are a total of 115 public projects, and 35 of those are NAVFAC. Other public projects (there are 80) include all those except NAVFAC. The sample sizes are large enough to justify using a "z-test for means with known variances." Again the null hypothesis, which we are testing, is that any differences in both samples are non-significant. The results are shown in Table 5.3

Table 5.3 z-Test Other Public vs. Navy

z-Test: Two Sample for Means	Public	Navy
	chgindex	*chgindex*
Mean	6.633	6.819
Known Variance	6.992	2.560
Observations	80	35
Hypothesized Mean Difference	0	
z	-0.437	
P(Z<=z) one-tail	0.331	
z Critical one-tail	1.648	
P(Z<=z) two-tail	0.662	
z Critical two-tail	1.959	

A 95 percent confidence level is assumed and a two-tail test is used. From the table z-critical is 1.959 and –1.959, z-value is -.4; therefore -1.959< -.4<1.959 meaning there is not sufficient evidence at the 95 percent confidence level to reject the null hypothesis. Any error is treated as normal sampling error and not as a difference in the two population means.

5.2.1 Other Metrics

The statistics that describe the change index values from each dataset are compared in Table 5.4. NAVFAC's average value is higher than other public sources, but lower than CII as a whole. NAVFAC appears to have a tighter range of values with less deviation and less variance. This seems accurate, because one would expect a military organization to be more standardized than private and other public sectors. In addition, one would expect less variation in a single organization versus a group of organizations. (Note: paragraph 5.1.2 explains the differences in sample sizes).

Table 5.4 Comparisons of Descriptive Statistics by data set for Change index

Change index	Navy	Other Public	Other CII
Mean	6.82	6.63	7.78636
Standard Error	0.2705	0.3280	0.1003
Median	6.92	7.14	7.86
Mode	5	7.86	8.57
Standard Deviation	1.600	2.644	1.71987
Sample Variance	2.561	6.993	2.95795
Kurtosis	-0.210	0.287	0.13098
Skewness	0.008	-0.924	-0.745
Range	7.14	10	7.86
Minimum	2.86	0	2.14
Maximum	10	10	10
Sum	238.69	431.19	2289.19
Count (n)	35	80	294
Confidence Level(95.0%)	0.549688	0.65524	0.19741

Similarly, NAVFAC values for Cost Growth seem to be more narrowly distributed about the mean than other public, and show less deviation and variance in Table 5.5.

Table 5.5 Comparisons of Descriptive Statistics for Cost growth

Cost growth	Navy	Other Public	Other CII
Mean	0.01	0.05	-0.034
Standard Error	0.0274	0.0209	0.0073
Median	0.0046	0.01	-0.03
Mode	0.487	0	0
Standard Deviation	0.162	0.182	0.141
Sample Variance	0.026	0.033	0.019
Skewness	1.134	1.169	0.382
Range	0.7449	1.264	1.087
Minimum	-0.2579	-0.527	-0.505
Maximum	0.487	0.737	0.582
Sum	0.43	4.14	-12.72
Count	35	76	362
Confidence Level(95.0%)	0.0558	0.0416	0.0143

The data results for the change cost factor seem to be widely distributed for each of the data sets. Table 5.6 shows how the change cost factors are distributed for each data set.

Table 5.6 Comparisons of Descriptive Statistics for Change Cost Factor

Cost factor	**Navy**	Other Public	**Other CII**
Mean	0.09	4.92	0.058
Standard Error	0.0301	4.7968	0.0108
Median	0.04	0.083	0.038
Mode	0.208	0	0
Standard Deviation	0.178	34.256	0.167
Sample Variance	0.032	1173.453	0.027
Kurtosis	16.337	50.997	112.996
Skewness	3.766	7.141	8.195
Range	0.959713	244.974	2.929
Minimum	-0.00871	-0.224	-0.748
Maximum	0.951	244.75	2.18
Sum	3.32	250.69	13.94
Count	35	51	238
Confidence Level(95.0%)	0.0611	9.6345	0.0213

The following box and whisker plot, Figure 5.4, helps illustrate the differences in the quartile ranges for the change index from NAVFAC, other public, and other CII projects. This graphically shows the tighter grouping of data about the NAVFAC data; however, it also shows room for improvement. Outliers were removed from the CII data set resulting in sample sizes slightly smaller than those presented in Table 5.4.

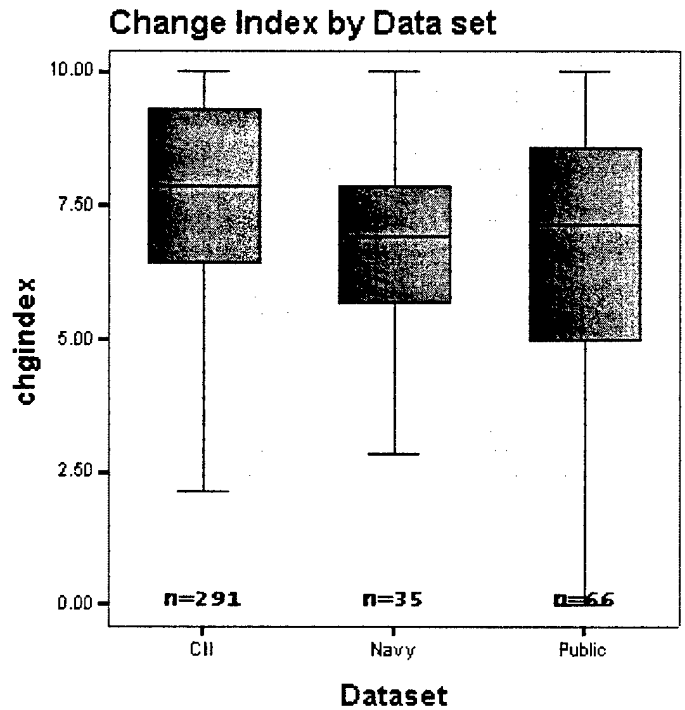


Figure 5.4 Adjusted Box and Whisker Plots for Change Index by database

NAVFAC projects show less variation than other public, or other CII projects. Interestingly, other CII projects (private) show less variation than other CII public organizations. The author expected the public sector to show less variation than the private due to the use of Federal Acquisition Regulations.

While the change index median for NAVFAC is lower than the other datasets, the actual statistics from Table 4.2 show that the mean (average) value for NAVFAC is higher than other public projects in the sample. Other statistics for performance metrics not described in this section are listed in Appendix E-1 to E-3.

5.3 ANOVA TESTS

The score on the metric called change index indicates the degree of project change management practice use by NAVFAC, other public, and other CII organizations. The formula for change index was discussed in Chapter 3.

A One–Factor Analysis of Variance Test (ANOVA) was used in order to compare the change index results between NAVFAC, other public and other CII organizations. Again the null hypothesis is that the means for each dataset are the same. The results of this test are shown in Table 5.7

Table 5.7 ANOVA for Change Index by Data Set

Anova: Single Factor						
SUMMARY		***Change Index***				
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	294	2289.19	7.78	2.96		
Navy	35	238.688	6.82	2.56		
Public	65	431.19	6.63	6.99		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	89.04	2	44.52	12.42	5.87E-06	3.02
Within Groups	1401.27	391	3.58			
Total	1490.32	393				

The ANOVA test reveals that at least one mean is indeed different for the metric change index between NAVFAC, other public, and other CII projects. The null hypothesis cannot be accepted and the results are considered to be statistically valid at the 95% confidence level, because the P-value (.000005) is smaller than alpha = .05. The previous z-test established that other public and NAVFAC means could be accepted as similar, it is reasonable to assume that the other CII mean is the different factor in the ANOVA tests.

The fact that there is a difference between the other CII, NAVFAC and the other public samples is not surprising. Common sense indicates that the differences can be partially explained by the fact that the other CII sub-sample is dominated by large industrial projects (77%). Projects less than $15M make up less than 45 percent of the CII sub-sample, and grass-roots projects make up only 36 percent of the total. By comparison, the NAVFAC sample and the other public sample consist of mostly buildings with some infrastructure projects; theses samples are mostly less than $15M, and mostly grass-roots in nature. NAVFAC projects and the other public projects are made up of similar groups of projects and their means have been accepted as equal. Other CII projects are made up of entirely different groups and their means must be accepted as different from NAVFAC and other public.

The question that needs to be answered is, "if projects in similar groups, size, and nature are compared will the variance in values for the Change Index be less pronounced?" In order to address this question, an ANOVA test like the one described in Table 5.3 was run on smaller groups of data with similar sizes, nature, and industries.

Since there are 3 data sets, and 3 main categories with which to break down the data sets (industry, nature, size) and 3-4 possibilities for each category it is possible to break down the datasets into 108 different groups for testing.

However, the limiting dataset is the NAVFAC dataset with only 35 projects. Breaking this data into 108 groups would leave many groups with one or less NAVFAC projects. Therefore only groups with sufficient sample sizes to be of value were tested.

To start, the author chose to examine the groups that had the majority of the NAVFAC projects. These groups and categories were grass-roots, buildings, and projects less than $15M. Table 5.8 below shows the results of an ANOVA for all Buildings.

Table 5.8 ANOVA for Change Index btw Datasets by Buildings

Anova: Single Factor			CHANGE INDEX			
SUMMARY			**Buildings**			
Groups	*Count*	*Sum*	*Average*	*Variance*		
Other CII	21	147	7.011	2.940		
O Public	51	327	6.405	7.878		
Navy	28	186	6.637	2.220		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	**F**	*P-value*	**F crit**
Between Groups	5.5	2	2.765	**0.523**	0.594	**3.09**
Within Groups	513	97	5.285			
Total	518	99				

Since the F statistic in this table is less than F critical (.52<3.09), the null hypothesis (Ho) cannot be rejected; there is insufficient evidence at the 95% confidence level to show a difference in means (Johnson 1997).

The ANOVA for the sub-group buildings (Table 5.8) was conducted first, and then ANOVAs were run for the sub-groups all grass roots, and then all projects less than $15M. Next variations of these sub groups were tested such as:

buildings <$15M, Industrial <$15M, grass roots <$15M, modernization <$15M, and add-on <$15M. In all over 36 ANOVA tests were run on these sub-groups.

The resulting ANOVA tables can be seen in Appendix G. There are two main points that this type of test indicates: 1) is there a significant difference in means between data sets such that the null hypothesis must be rejected, and 2) is the test statistically valid to the 95% confidence level. Appendix G shows the results of 17 ANOVAs. They are shown because they had a sufficient number of NAVFAC projects to make comparisons worthwhile. The other nine ANOVA test by various sub-groups did not have enough projects to provide any information.

The result of these tests showed that in most cases, when comparing data sets by similar sub-groups the differences in mean values for the change index grew smaller; however, the statistical validity gets smaller as the sample size gets smaller. These findings are somewhat predictable. Based on these tests the three data sets and their sub-sets were compared

5.3.1 ANOVA on Other Performance Factors

The preceding analysis examined the similarities between data sets for the Project Change Management practice use metric called change index. The change index has been shown by CII to correlate with certain project performance factors as discussed in Chapter 3. ANOVA tests conducted for the performance factors cost growth, and schedule growth found statistically significant differences in project performance between the data sets tested. The results are shown in Tables 5.9 and 5.10.

Table 5.9 ANOVA for Cost Growth by Dataset

Anova: Single Factor							
SUMMARY			Cost growth				
Groups	*Count*	*Sum*	*Average*	*Variance*			
CII	376	-12.72	-0.034	0			
Other Public	76	4.136	0.054	0			
Navy	20	0.396	0.02	0			
ANOVA							
Source of Variation	*SS*	*df*	*MS*	**F-stat**	*P-value*	*F crit*	
Between Groups	0.5212	2	0.261	12	1E-05	3.0149	
Within Groups	10.616	469	0.023				
Total	11.138	471					

The F statistic in Table 5.9 is greater than F critical (12 > 3.01); therefore, Ho is rejected. These are significant differences that are too large to explain by sampling error alone (Johnson 1997).

Table 5.10 shows that the F statistic, which is 6.5, is greater than F critical, which is 3.01; therefore, there is sufficient evidence at the 95% confidence level to reject Ho. This means there are differences in schedule growth between the data sets.

Table 5.10 ANOVA for Schedule Growth by Dataset

Anova: Single Factor			Schedule growth			
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	342	40.822	0.119	0.7		
Other Public	72	37.282	0.518	2		
Navy	19	11.101	0.584	1.4		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12.286	2	6.143	6.5	0.002	3.0167
Within Groups	408.37	430	0.95			
Total	420.66	432				

Figure 5.5 shows a box and whisker plot of the cost growth for each data set. Negative numbers indicate a better outcome (cost reduction) in most cases.

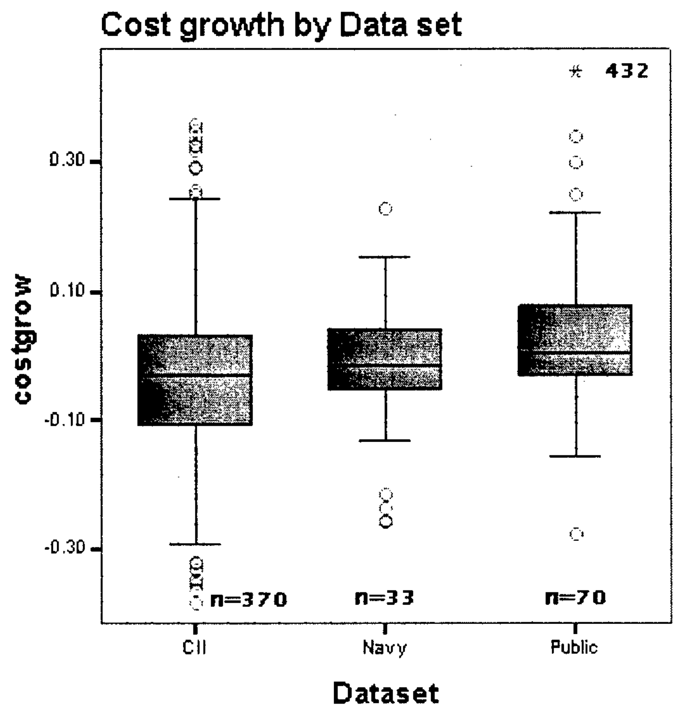


Figure 5.5 Cost Growth Performance by Data set

CII projects have a very low average cost growth factor of -.03, NAVFAC averages .01 cost growth, and other public averages .05. However, with the limited number of projects used in this sample, this research does not pretend to predict the performance of the entire population of NAVFAC projects, other public projects or CII projects. There is sufficient evidence; however, to develop predictive models for cost growth based on change index.

Is the impact of the change index on the performance factors mentioned above the same for each data set? CII has been able to show improvements in cost growth corresponding to increase in the change index. To answer the question "Can NAVFAC expect to see similar results?" the following analysis was performed.

5.4. REGRESSION

A simple linear regression between the change index values and performance factors (cost growth, cost factor, and schedule factor) was executed for each data set; a total of 12 in all. These can be seen in more detail in Appendix H. Regression was performed using both Excel, and SPSS 8.0 and the results were identical in most cases.

Regression is used to establish the relationship between two variables, the change index and cost growth. The results tell the direction and strength of the relationship, along with the statistical significance. In regression analysis, the results are shown by an equation of the best-fit line (the prediction line that best approximates the data) $y=\beta_1x+\beta_0$. The beta coefficient indicates the slope of the line. The steeper the slope, the greater the impact x has on y (Diekhoff 1996). The null hypothesis (Ho) is that $\beta_1 = 0$, meaning there is no relationship. Figure 5.6 below shows the actual regression line for the other CII data set.

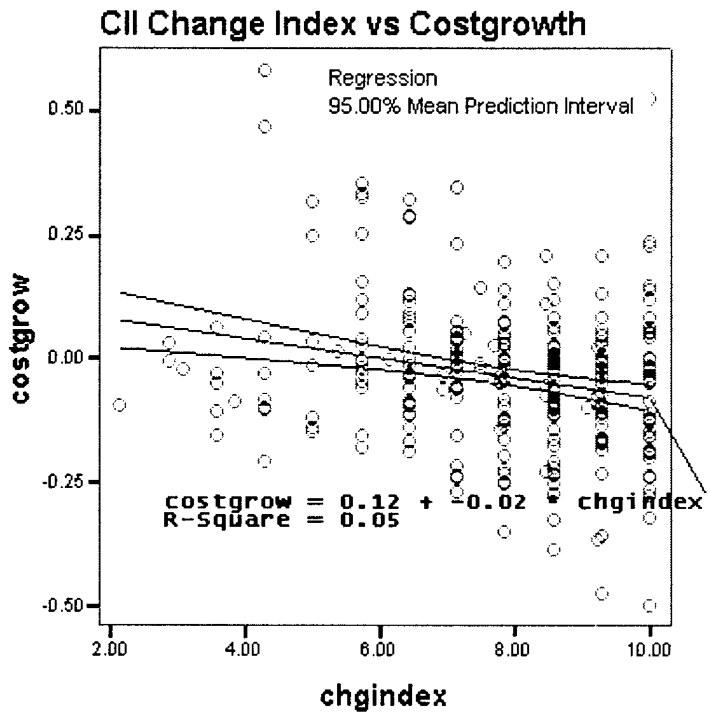


Figure 5.6 Other CII Change Index versus Cost Growth (n=292)

The equation of the line in the above graph is: **Cost growth = .12-.02*change index**. This says for every 1-point improvement in "change index" cost growth is reduced by 2%. The R^2 in this example is .05 so the relationship is weak. For other public projects the regression can be seen in Figure 5.7.

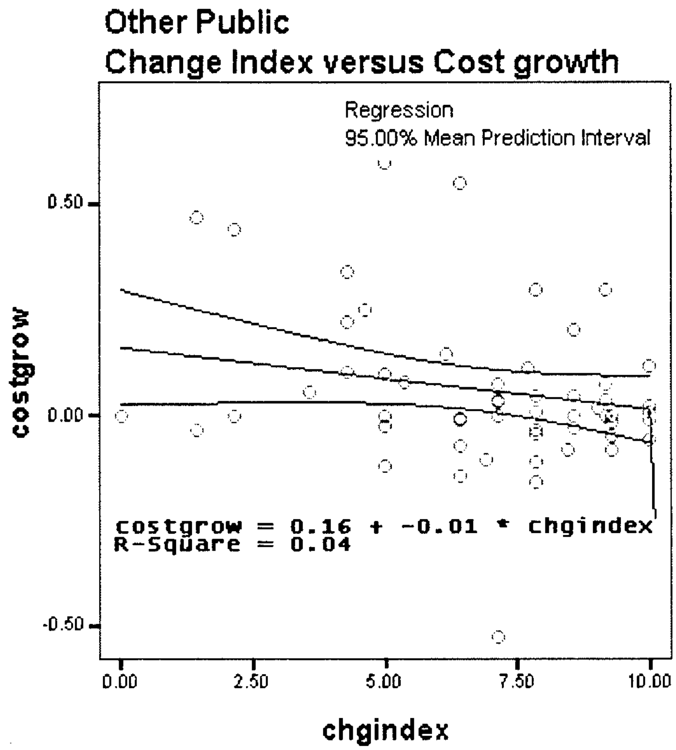


Figure 5.7 Change Index vs. Cost growth for Other Public (n=60)

A series of regressions similar to those shown in Figure 5.7 were completed and the results are shown in Table 5.11. The table shows the Beta coefficient, the significance (F sig), and the strength of the fit (R^2) between change index and the performance factors: cost growth, cost factor, and schedule growth.

As shown in Table 5.11 for *Other CII* projects, a one-point improvement in the change index score corresponds to a -2 % (β_1) improvement in cost growth. The goodness of fit is 5 % (R^2); the significance or P-value (F sig) is .00005, which is less than the α. Alpha (α) =.05 for a 95 % confidence level.

Table 5.11 Summary of Regression Statistics

Data Set	Linear Regression	β_1	n	F sig	R^2
Other CII					
Change Index vs.	Cost growth:	-.02	292	0.00005	0.05
	Cost factor:	-.008	233	0.21	0.006
	Schedule growth:	-.02	267	0.079	0.026
Other Public					
Change Index vs.	Cost growth:	-.015	60	0.12	0.04
	Cost factor:	-.002	45	0.70	0.003
	Schedule growth:	-.017	57	0.067	0.05
Navy					
Change Index vs.	Cost growth:	-.016	35	0.361	0.03
	Cost factor	+.013	34	.48	.014
	Cost factor: *[1]	-.007	19	0.59	0.016
	Schedule growth:	-.23	31	0.07	0.11

The regressions and statistics shown in Table 5.11 were produced in Excel, the complete list of statistics and line plots are available in Appendix H. The values listed in Table 5.8 indicate, for all three sets of data, that as the scores for change index improves cost growth declines between 1.5 and 2%. These initial associations are not very strong (.03 and .05); however, that is to be expected since these data sets make up a very diverse group of projects in different industries, with different sizes and different natures. In addition, many other factors may impact performance indicators on a typical project. Further study by select groups and categories might have better correlations and more statistical significance.

Table 5.11 also indicates that the Change Index has an impact on schedule growth and on the change cost factor. The initial regression on the cost factor indicated a β_1 = .013, a positive growth in the cost factor. This result is not

[1] This regression on the change cost factor was performed on All Navy – grass-roots projects only.

normally expected and will be examined in more detailed later in this thesis. The change index had the largest impact on schedule growth for NAVFAC projects where the regression indicates a R^2 of .11 with a .07 level of significance (close to the 95% confidence level.) and a 23% reduction in schedule growth for every one-point improvement in change index. This regression can be seen in Figure 5.8.

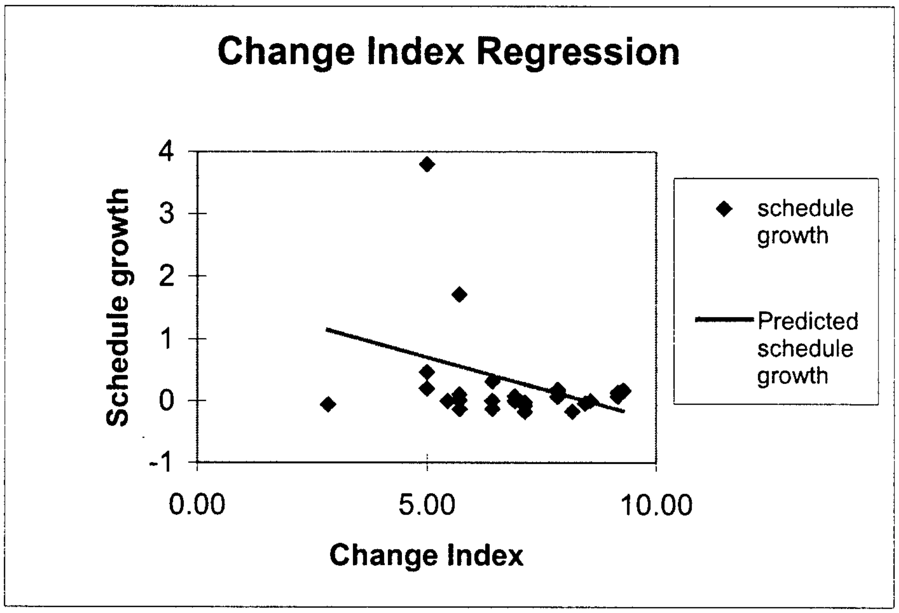


Figure 5.8 Change Index vs. Schedule growth –NAVFAC (n=31)

5.4.1 Specific NAVFAC Groups

Since the author is interested in NAVFAC projects, more regressions of NAVFAC data were executed for each industry group by size, and nature. The majority of all NAVFAC projects in the database are grass-roots projects less than <$15M, which makes this group a logical one to examine further.

The regression results of NAVFAC grass roots projects less than $15M (Table 5.12) show a very strong association R^2= .34 between the change index and cost growth and is much higher than any of those previously examined (although consisting of a relatively small sample size). The equation of the line is **Cost growth = .68 -.09 * change index.** This indicates a 9% reduction in cost growth for every one-point improvement in the change index. The beta coefficient (.09) is larger than those shown in the previous table, this indicates that for grass-roots projects less than $15M the change management practices have a big impact. Figure 5.9 illustrates this via the steepness of the line. Notice it is steeper than the line in Figure 5.6.

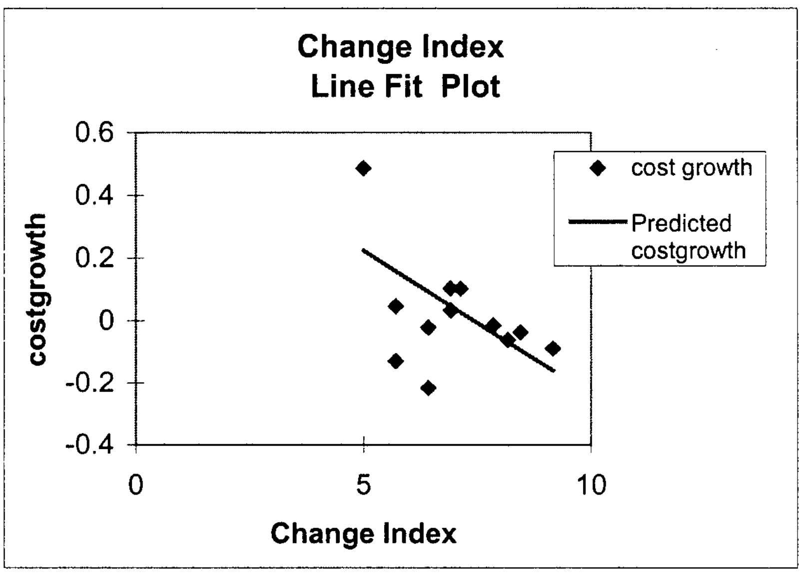


Figure 5.9 Regression line for NAVFAC Grass-roots <$15M (n=14)

This process was repeated for several different sub-groups of data. The only other findings of interest were for all grass-roots projects and all modernization projects; these results are shown in Table 5.12 along with the statistics for Figure 5.9 above. The complete regression statistics are included in Appendix I.

Table 5.12 Regressions of NAVFAC Projects by Sub-groups

Navy	Regression	β_1	n	F-sig	R^2
Grass-roots (<15M)	Change Index vs. Cost growth:	-.09	14	0.03	0.34
Grass-roots	Cost growth:	-.08	20	0.16	0.37
Buildings	Cost growth:	-.06	27	0.14	0.21

Grass-roots projects as a whole show a 37% association between the change index and cost-growth, which is by far the strongest tested; however, the beta coefficient of -.08 is less than those of grass roots less than $15M. Modernization projects also showed a strong association (28%); however, with less significance, a smaller sample size, and less impact. For all of these specific NAVFAC sub-groups the sample sizes are quite low. Other groups such as add-ons between $15-50M had even fewer projects making regression non-feasible.

As mentioned earlier the initial regressions for the cost factor indicated a positive growth in cost factor as a result of increase in the change index. These results did not seem logical. According to the initial hypothesis, improving the change management process on a project should reduce the number and cost of change orders. The change cost factor is cost of changes divided by total cost of the project. It is possible that one could follow the elements of the change index perfectly and find some legitimate reason for modifying the contract. For instance, a legitimate reason may be the result of value engineering or unforeseen site conditions. The cost factor by itself is of limited value; for example, a perfectly and find some legitimate reason for modifying the contract. For instance, a legitimate reason may be the result of value engineering or unforeseen site conditions. The cost factor by itself is of limited value; for example, a modification due to value engineering may result in a large overall cost reduction; however, the cost factor would still be large. In fact, closer examination of Navy project number P6 from the Analysis of NAVFAC survey indicates a $17M change order took place; however the final project ended up $12M under budget.

Also, Navy project number 8 was the only project over 100 million dollars. It was a design build project, involving add-ons, modernizations and grass roots construction over a time frame of five years. Due to the nature of this project numerous scope changes (311) and development changes (40) took place accounting for $50M dollars. A separate regression shown in Table 5.11 was completed without this project. The results showed a reduction in the cost factor due to the change index, which matched initial predictions.

The average change cost factor for all NAVFAC projects, from Table 5.6 is 0.095. This indicates that 9.5% of total project costs for NAVFAC projects, or $407M can be attributed to change orders. NAVFAC's average change index (6.82) is in the 3rd quartile for CII projects. A 2.5-point improvement (from Figure 4.16) is needed to get into the first quartile of CII projects. From Table 5.11 a one-point change in the change index for grass roots projects equates to 0.7% reduction in the change cost factor. Although a rough estimate, a 2.5 potential improvement in the change index could result in a 1.75% reduction in the cost factor. This could potentially reduce change orders by approximately $7 million dollars ($407M * 1.75%).

5. 4 PRACTICE USE

The change index values presented above are based on answers to the 14 PCM practice use questions discussed previously. This section looks at the survey responses to the change management practice use questions more closely in order to determine the extent of practice use.

5.4.1 NAVFAC Practice Use

The Navy metrics for the change index scores presented in section 4.2 were derived from the answers presented in Table 5.13, which came from the 15, returned "Analysis of NAVFAC Surveys" and the 20 NAVFAC projects in the CII database.

Table 5.13 Practice Use Summary Results for NAVFAC

Project Change Management Practices	Yes	No
1. Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?	34	1
2. Was a baseline project scope established early in the project and frozen with changes managed against this base?	34	1
3. Were design "freezes" established and communicated once designs were complete?	32	3
4. Were areas susceptible to change identified and evaluated for risk during review of the project design basis?	30	4
5. Were changes on this project evaluated against the business drivers and success criteria for the project?	30	5
6. Were all changes required to go through a formal change justification procedure?	26	9
7. Was authorization for change mandatory before implementation?	20	10
8. Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?	19	15
9. Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?	17	16
10. Did the project contract address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract?	14	16
11. Was a tolerance level for changes established and communicated to all project participants?	10	25
12. Were all changes processed through one owner representative?	7	22
13. At project closeout, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?	7	27
14. 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?	34	1
Sum	315	154
Percent of Total Possible	64%	31%

Since there are 35 survey results and 14 questions, there are 490 potential responses. Of the 490 possible responses 469 were answered yes or no, and 6% or 20 were considered unknown. Respondents indicated they are using the majority of the practices (67%.) However, over a quarter (27%) of the responses were negative.

Out of the 14 practice elements 8 are used more than 80% of the time, two are used 50% of the time, three are not used the majority of the time, and one is not used 80% of the time. More detailed breakouts by element for each data set are available in Appendix J-1 to J-3. Figure 5.10 shows the break down of percent of practice elements.

Figure 5.10 shows the overall combined NAVFAC use of change management practice elements sorted in the order they are used.

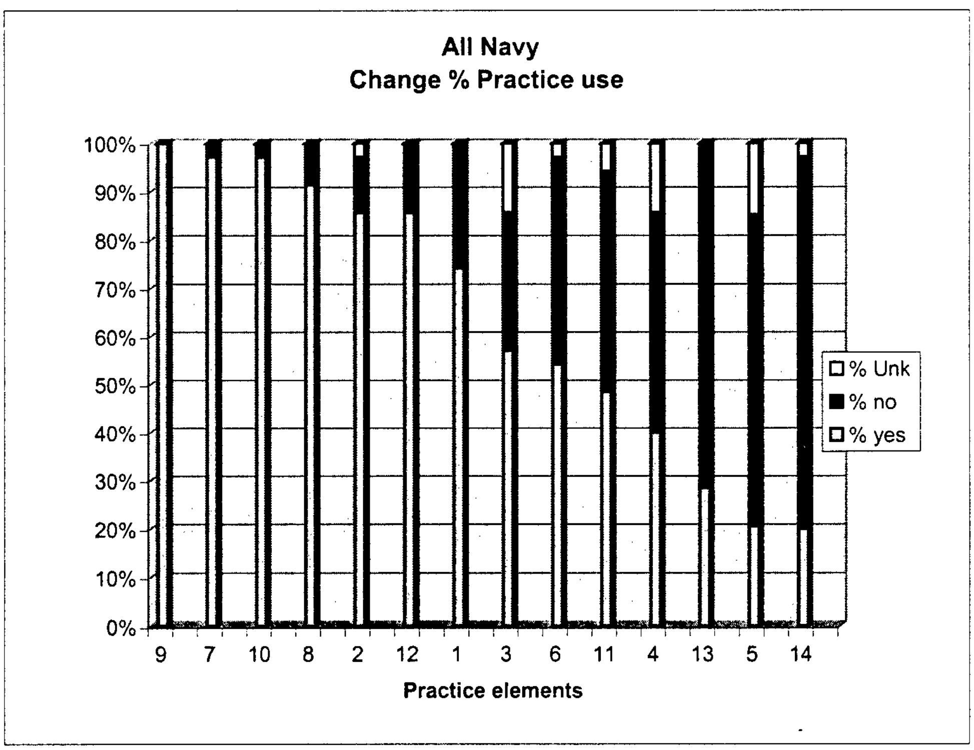


Figure 5.10 All NAVFAC Practice use sorted in Order (n=35)

Practice elements 9, 7, 10, 8, and 2 are used by nearly everyone (more than 90% of the time) and only 1 response from this group was unknown. The majority use practice elements 12, 1, 3, and 6 (between 55 -90% of the time) but there are quite a few negative responses (15 to 40%.) Elements 11 and 4 are essentially even at 45% used and 46% not used with approximately 10% undecided. A clear majority of projects are not using elements 13, 5 and 14. Table 5.14 shows the practice elements grouped by use.

Table 5.14 NAVFAC Practice Elements Grouped by Use

Project Change Management Practice Elements
Highly Used
9. Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?
7. Was authorization for change mandatory before implementation?
10. Did the project contract address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract?
8. Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?
2. Was a baseline project scope established early in the project and frozen with changes managed against this base?
Majority of the Time
12. Were all changes processed through one owner representative?
1. Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?
3. Were design "freezes" established and communicated once designs were complete?
6. Were all changes required to go through a formal change justification procedure?
Partially Used
11. Was a tolerance level for changes established and communicated to all project participants?
4. Were areas susceptible to change identified and evaluated for risk during review of the project design basis?
Rarely Used
13. At project closeout, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?
5. Were changes on this project evaluated against the business drivers and success criteria for the project?
14. 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?

Elements 3, 4, and 5 received over 14% unknown responses; perhaps these questions are either not fully understood or not applicable to NAVFAC project managers. In the author's experience, establishing design freezes and establishing areas susceptible to risk are both understandable and applicable to NAVFAC, therefore, it is likely that the respondents were not using these practices. Practice element 5, concerning evaluating changes based on the business drivers and success criteria, is hard to apply in the NAVFAC setting; therefore, it is not surprising to see a high unknown response rate. This will be discussed further in Chapter 6.

5.4.2 Other Public Agencies Practice Use

Other CII public agencies average practice use is lower than NAVFAC's as a whole as illustrated in Figure 5.11. Overall results from the other public sample shows 64% responding "yes," compared to 67% for NAVFAC. The other public data shows 33% responding "no," compared to 27% for NAVFAC. The detailed results are shown in Table 5.11.

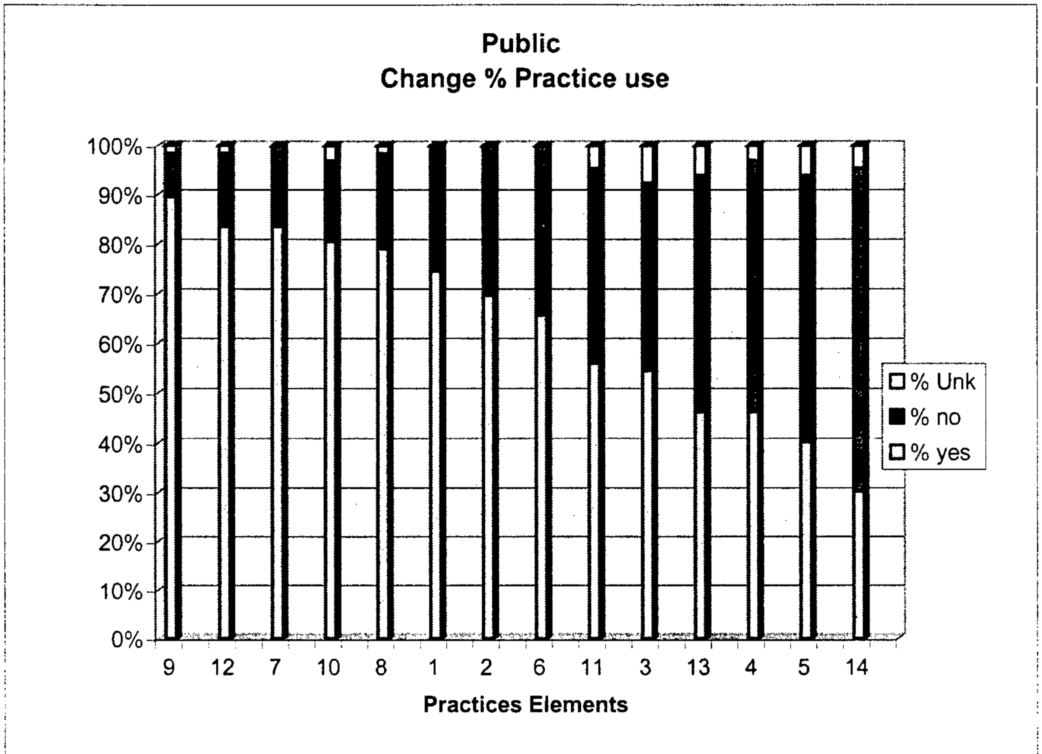


Figure 5.11 Percent Practice use for Other Public Agencies

The order of the most used practice elements for other public agencies is not much different than for NAVFAC. Elements 9, 12, 7, and 10 are used most, 80-90% of the time. Elements 8, 1, 2, 6 are used 60-70% of the time. Elements 11 and 3 are used slightly more than 50% of the time. Practice elements 4, 5, 13, 14 are all not used most of the time. In order, practices 3, 13, 5, 11, 14, and 4 had the highest percentage of unknown responses. A more detailed explanation of these elements on future surveys would likely improve responses and therefore improve the research findings.

5.4.3 Other CII Owners Practice Use

A graph similar to Figure 5.11 for other public agencies is given in Figure 5.12. It illustrates which practice elements are used most often by other CII organizations.

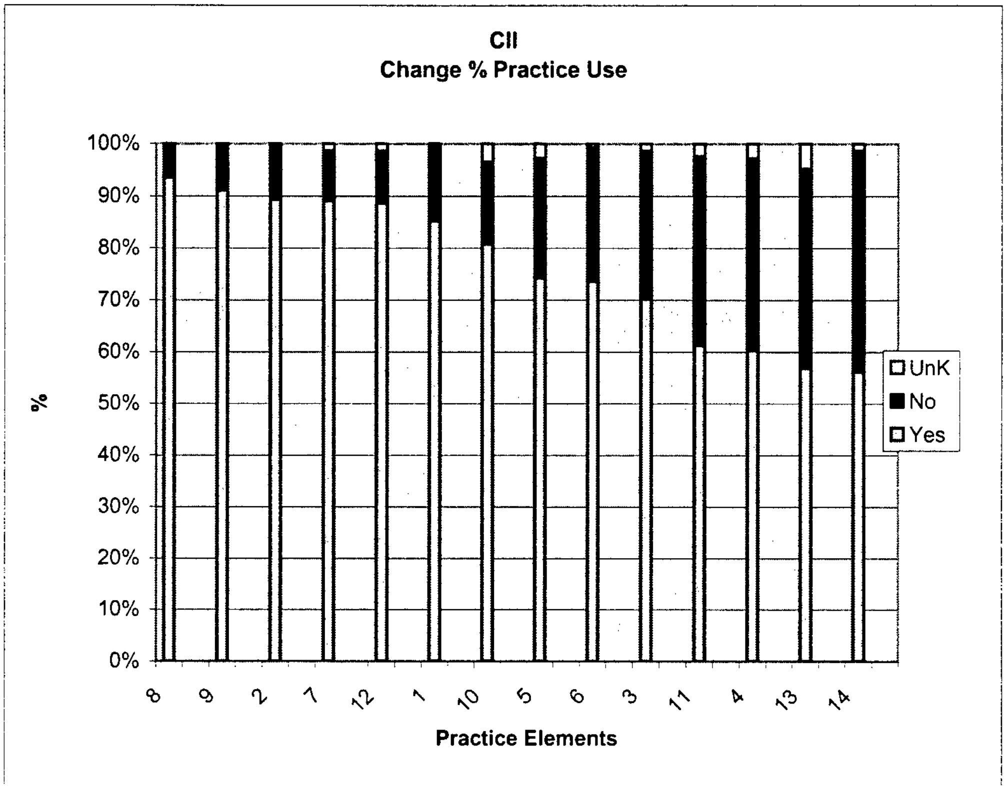


Figure 5.12 Percent Practice use for Other CII

As illustrated, practice elements 1, 2, 7, 8, 9, 10, and 12 are used more than 80 percent of the time. Practice elements 3, 5, 6, and 11 are used between 60 and 80 percent of the time, while 4, 13, and 14 are only used between 50 and 60 percent of the time. The following chapter will summarize the implications of these findings to NAVFAC.

percent of the time. The following chapter will summarize the implications of these findings to NAVFAC.

CHAPTER 6

Implications to NAVFAC

6.0 FINDINGS

The thesis has demonstrated that while there are some differences in the industry groups and project nature NAVFAC projects, other public projects, and other CII projects all come from similar populations. When comparing similar industry groups by nature and size the three datasets can be statistically compared. Although the sample sizes used in this research are small, they do illustrate the potential impact of effective use of the Project Change Management practices identified by CII on certain performance metrics.

The impact of Project Change Management practices on NAVFAC was shown to be similar to the impact on other CII projects. However, the CII best practice PCM was analyzed in isolation from the other 10 CII best practices such as: Pre-Project Planning, Constructability, and Team building. The cumulative or synergistic effect of using all these practices at once was not examined. Dr. David Hudson's work shows the cumulative effect of several of these practices working together (Hudson 1996).

6.1 IMPACT OF PRACTICE USE

The vast majority of NAVFAC projects, those grass roots buildings less than $15M can benefit from change management. Each 1-point improvement correlates to a 9% reduction in cost growth (β_1 from Table 5.12.) A 3.18 potential improvement multiplied times 9% provides for a possible 26% reduction in cost growth. NAVFAC is executing $4.3 billion in construction contracts each year. The average cost growth for NAVFAC, from Table 5.2, is 1.24% that equates to $53 million in cost grow each year. A 26% reduction in cost growth equates to a $13.5 million potential savings from reductions in cost growth alone.

Additionally, there are potential benefits from reductions in schedule, and claims. The 2.3% reduction in schedule growth (β_1 from Table 5.11) multiplied by the 3.18 potential improvement in Change index produces an approximate 7% reduction in schedule growth. However, by itself this may tend to overstate the benefits of change management.

The improvements in cost, schedule, and change orders are not additive. One should not expect to benefit from a cost reduction due to schedule, plus a cost savings due to reduction in number and size of change orders, plus a 9% reduction in cost growth. Instead the impact of change management on these factors is a combined improvement.

6.2 OBSERVATIONS

While the survey responses for NAVFAC showed less variation than the CII database, there were some inconsistencies in the answers to the practice use elements. Some of the responses were not consistent with the information provided in the Field Officers Student Guide. The officers questioned may have been confused by the questionnaire, or once in the field they are not retaining the information being taught in the Field Officers Student Guide (CECOS 1999).

Overall NAVFAC's cost performance is better than other public CII members, but is in the third quartile of other CII members for cost growth.

In the general, NAVFAC use of the project change management practice is above that of other public agencies, but behind CII as a whole. NAVFAC is in the 3rd Quartile of CII Companies using the project change management practice. Table 6.1 shows the practice elements ranked in the order in which they are used. The most often used are on the left, the least often used on the right.

Table 6.1 Practice Use ranked by Use

Comparison of Practices Used in Order														
Other CII	8	9	2	7	12	1	10	5	6	3	11	4	13	14
NAVFAC	9	7	10	8	2	12	1	3	6	11	4	13	5	14
Other Public	9	12	7	10	8	1	2	6	11	3	13	4	5	14

From this Table we see that the practice elements least used by NAVFAC are very similar to those least used by CII and other public agencies. Elements 3, 4, 11, 13, and 14 are used the least by all three groups, and they are used in approximately the same order. The biggest difference between CII and NAVFAC seems to be in practice element number 5.

Practice element 5: Evaluate changes against the basic business drivers and success criteria for the project. It is unlikely that the ROICC office personnel would have access to the original business drivers; particularly since the timeframe for MILCON projects can be 5 years. However, it is reasonable to expect that the customer or customer liaison (often this is Public Works personnel) could provide some success criteria particularly in regard to mission fulfillment. It is entirely possible for this to become a requirement in future projects. The data show that this element is used only 20% of the time. Each element is worth .72 points on the index and cost growth/point is -.09; therefore, improving this practice element has a potential to reduce cost growth by 5.4%.

Practice element 6: Requires all changes to go through a formal change justification procedure. This element is being used only 54% of the time, and 3% of those surveyed were not sure if this was being done. According to the standard modification process discussed in Chapter 2, most NAVFAC respondents should have answered yes to this practice. Forty-six percent of those NAVFAC personnel surveyed were unaware of the standard process, ignored the standard procedure, or were confused by the question.

The wording of the question may have been confusing. The question asked if changes go through a " formal justification procedure." Is a standing operating procedure considered a formal procedure? Many modifications are approved according to SOP at the lowest level by contracting officers. Project managers might not consider this a formal procedure, but they should. This needs to be corrected.

Practice element 11: Establish tolerance levels for changes and communicate these to all participants. The Navy's contracting manual (P-68) does provide for basic thresholds for change approval such as those discussed in chapter 2. However, tolerance levels defined specifically for each project based on the project success factors and potential weaknesses are not being formally established and communicated. This element is being used only 49% of the time.

It is entirely possible to implement this practice element within government contracting and NAVFAC in particular. A 51% improvement on this practice alone would improve cost growth by 3.28%.

Practice element 13: Evaluate changes and their impact on project cost and schedule performance at project closeout, for future use as lessons learned? Only 29% reported use of this practice element. Clearly most of the time this element is not used. This is perhaps a function of the increasing workloads, within NAVFAC, due to budget and personnel cuts over the last decade. Many ROICC personnel have numerous projects to deal with at any given time. Stopping to complete or evaluate the changes of a completed project does not get much consideration, particularly when the pressure is on to complete the next project.

However, adopting this practice element as standard procedure can be done in a reasonable manner and should be considered. While it appears to take additional time, the data presented herein shows these elements can reduce schedule growth.

Practice element 14: Organize the project in a Work Breakdown Structure (WBS) format and assign quantities to each WBS for control purposes prior to total project budget authorization? This practice element is the least used, only 20% of the time, according to the survey results. This is due to the nature of Navy contracting. The pre-project-planning and business planning is done 4-5 years in advance of the project by a separate staff, the Public Works Department. A detailed work breakdown structure is usually not completed until the contract is ready to be advertised. Prior to award, a WBS could be completed along with the government estimate and sent to the ROICC. This should be accomplished by Public works, or an A/E firm prior to contract advertisement and could be included in the complete contract package that is sent to the contracting officer.

Design-build projects are becoming more and more frequent within NAVFAC and may render this practice element more useful. The concept of using a WBS for control purposes would also be valuable in a partnering arena. For public projects this element might be better utilized if recommended for use as a control mechanism at or prior to contract award rather than during the pre-project planning stage.

While some of the practice elements for change management discussed may seem as if they do not apply to NAVFAC, all of them when examined in detail can be applied in some fashion.

Finally, the average Change Index for NAVFAC projects presented in chapter 4 is 6.82. A 3.18-point improvement on the Change index is possible if each practice element described above is implemented. This can have a significant positive impact on NAVFAC project's cost and schedule.

CHAPTER 7

Conclusions

7.0 Conclusions

The overall goal of this study was to identify areas where the Navy might be able to improve its construction change management practices. To meet this goal the following objectives were set:

1. Characterize the Navy's change order management best practice use in regard to the CII member organizations and to other public agencies.

   While NAVFAC's change order management practice use is higher than other public agencies evaluated in this study, it lags behind CII as a whole. More can be done within the framework of the Federal Acquisition Regulations and the P-68 to improve performance.

2. Analyze change order performance for NAVFAC projects identified through surveys.

   For this sample of 35 NAVFAC projects, change orders accounted for 11% of the cost and 319 weeks of the combined schedules. If these numbers were applied to all NAVFAC projects, approximately 4.2 billion in total construction, the impact would be approximately 1 billion dollars in changes. This indicates a significant potential for improvement through use of PCM and other CII best practices.

3. Recommend areas where NAVFAC might be able to improve performance, and determine which methods can be used to accomplish this improvement. These recommendations are:

- **Incorporate Change Management**

NAVFAC can benefit from the change management practice elements identified by CII and outlined in this study. The Navy's Contracting Manuel (P-68) should be modified to include these change management practice elements as standing operating procedures (SOP).

All of these best practice elements should be incorporated into the Field Office Management Course and taught at the Civil Engineer Corps Officer School (CECOS). Specifically, the following practice elements have been identified in this study as areas that need significant improvement.

1. Evaluate changes against basic drivers and success criteria.
2. Identify areas susceptible to change and evaluate for risk during review.
3. Evaluate changes and their impact on cost and schedule at project closeout.
4. Establish tolerance levels for changes and communicate these to all.
5. Organize the project into WBS format and assign quantities to each activity for control purposes

Practice element #14, the use of a WBS as a control mechanism, should be taught in the Facilities Management course as well. It should become SOP for designers, or project engineers to prepare the WBS and to include it in the project package for contractibility review.

- **Better Utilize CII**

NAVFAC should take better advantage of its membership in CII by providing project data for 100% of all projects. NAVFAC does not have an organization equipped to perform the type of serious benchmarking and research needed to make continuous quality improvement a reality. CII's use of the world wide web for data collection can help can help accomplish this effort in a more timely and affordable manner.

More rigorous statistical analysis can be easily accomplished by CII with the addition of more NAVFAC projects to the database. This would allow for detailed studies by project size, contract type, industry, and project nature. This will provide better insight into the actual practices being used on certain types of Navy projects.

- **More Detailed Analysis**

Further study involving multiple regression of individual practice elements should be accomplished for all CII organizations. This may lead to the rejection of some individual practice elements, and the addition of others.

CII may consider adding new best practices elements to improve project change management such as Functional Analysis Conceptual Design, and new virtual project management software may have a positive effect on cost growth as well. Further studies are needed to examine these new techniques in detail.

- **NAVFAC Use of Other Practices**

NAVFAC should look more closely at the other best practices outlined in CII publications. Currently CII prepares a "Key Report" for each member (including NAVFAC) detailing all performance metrics and all best practices. This report needs much wider dissemination! This should be accomplished by sending copies of this report to the NAVFAC Executive Steering Committee, CECOS, and to all Field Divisions.

The fact remains that every construction project, regardless of its size and industry sector deals with change orders. This thesis has demonstrated how a positive project change management system can have an enormous impact on the Navy Facilities Engineering Command.

Other Observations

There were inconsistencies in answers to the question about standard procedures for processing change orders. This area should be stressed more heavily at CECOS along with methods for continuous quality improvement.

Finally, further study involving more projects is needed to establish these findings in a more statistically significant manner.

Appendix A Glossary of Terms

Appendix A Glossary of Terms

NAVFAC Terms:

Equitable adjustment - the difference between what it would have reasonably cost the contractor to perform the work as originally required and what it reasonably costs the contractor to perform the worked as changed.

Contract modification - Any written change in the terms of the contract.

Bilateral modification - A contract modification that is signed by both the Contracting Officer and the contractor. They are used to make negotiated equitable adjustments and to reflect other agreements of the two parties that modify the terms of the contract.

Supplemental agreement - A contract modification that is accomplished by the mutual action of both parties.

Unilateral modification - A contract modification that is signed only by the Contracting Officer. They are used to make administrative changes, issue change orders, make changes authorized by other clauses (ex: Options and Suspension of Work clauses), and issue termination notices.

Administrative change - A unilateral contract change, in writing, that does not affect the substantive rights of the parties.

Change order - A written order, unilaterally signed by the Contracting Officer, directing the contractor to make a change that the Changes clause authorizes the Contracting Officer to order without the contractor's consent.

Definitization - An agreement or determination of the contract terms, specifications, pricing, and/or time that converts an undefinitized contract action into a definitized contract.

Definitized Bilateral Modification - A contract modification for which both parties have agreed to the terms, specifications, price, and time for the additional work. Required additional work may be authorized by clauses, such as the changes and differing site conditions clauses. If this work is pre-priced, a definitized bilateral modification is issued.

Undefinitized Bilateral Modification - A contract modification that does not quantify a final agreeable change to the terms, specifications, price, or time. This modification always requires a follow-on modification to document the complete and final equitable adjustment. When the work cannot be forward priced without adversely affecting the interest of the Government, but a maximum price can be agreed with the contractor, an undefinitized bilateral modification is issued.

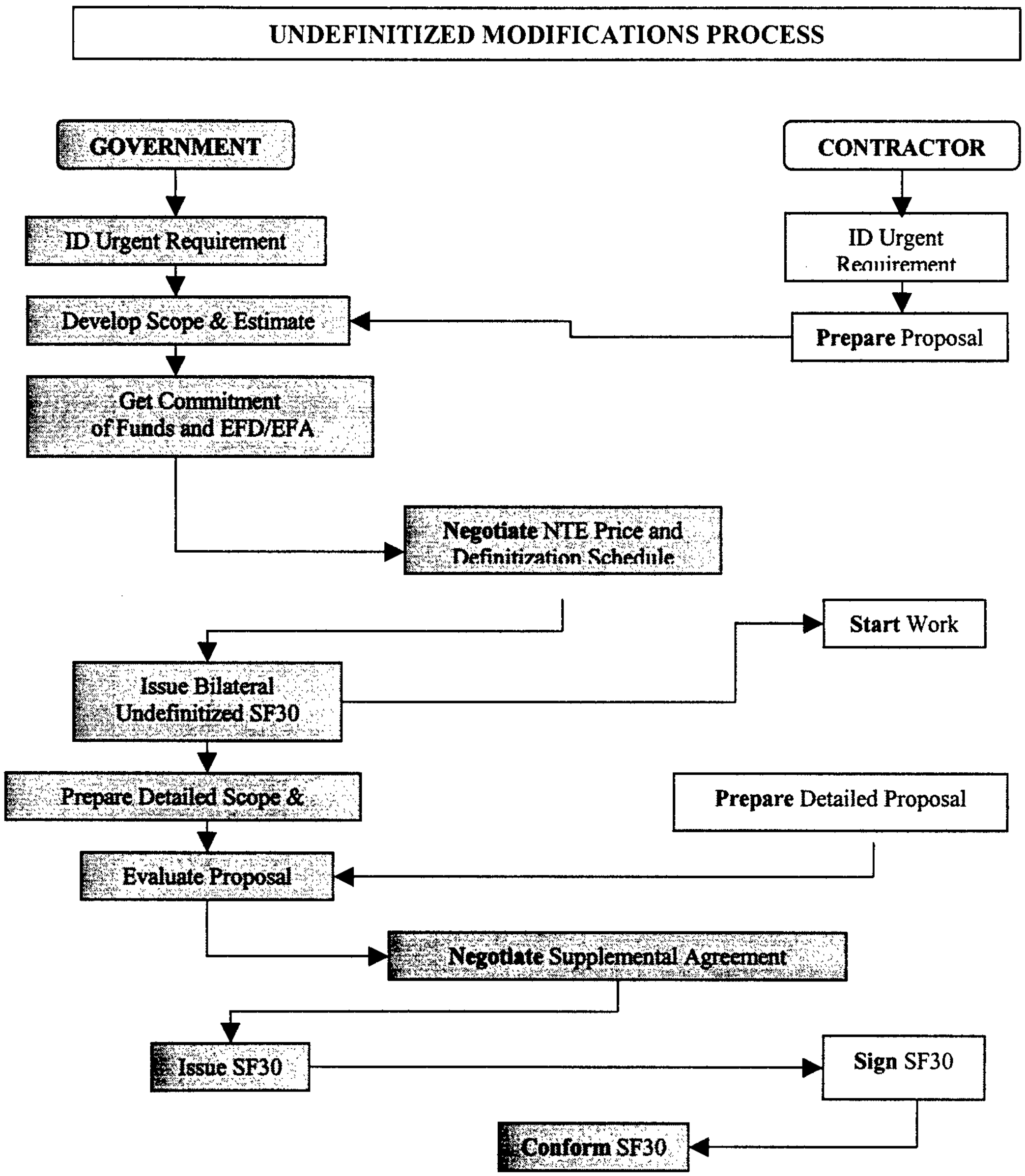
Undefinitized Unilateral Modification - A contract modification, signed only by the Contracting Officer, which has not been agreed to by the contractor, and the changes to the terms, specifications or price of the contract have not been established.

If time does not permit, or it is impractical to negotiate a maximum price, an undefinitized unilateral modification is issued. All unilateral modifications must be in scope. This type of change order must be followed by a supplemental agreement.

Definitized Unilateral Modification - A contract modification signed only by the Contracting Officer that quantifies a change in the contract terms, specification, pricing, or time of a contract. The Contracting Officer must deem the terms an equitable adjustment (fair and reasonable).

When unable to negotiate an equitable adjustment, a definitized unilateral modification is issued for the dollar amount and time that has been determined to be fair and reasonable. All unilateral modifications must be in scope.

Appendix B NAVFAC Modification Process


UNDEFINITIZED MODIFICATIONS PROCESS
GOVERNMENT
CONTRACTOR
ID Urgent Requirement
ID Urgent Requirement
Develop Scope & Estimate
Prepare Proposal
Get Commitment of Funds and EFD/EFA
Negotiate NTE Price and Definitization Schedule
Start Work
Issue Bilateral Undefinitized SF30
Prepare Detailed Scope &
Prepare Detailed Proposal
Evaluate Proposal
Negotiate Supplemental Agreement
Issue SF30
Sign SF30
Conform SF30

Appendix C BM&M Survey

CII Benchmarking and Metric
Owners (Version 3)

The data collected by this form begins the third round of data collection for CII's benchmarking and metrics system. The data will be used to establish performance norms, to identify trends, and to correlate execution of project management processes to project outcomes. It will form part of a permanent database. Through such correlation across many companies and projects, opportunities for improving your company's project performance will be identified. Following the data collection and metrics calculations, each company will be provided project and company aggregate key reports for comparison with the database benchmarks. It is important that you retain a copy of this questionnaire for your records and future analysis. **All data will be held in strict confidence.**

When you have completed the questionnaire, please return it to your Company's Benchmarking Associate by **June 1, 1998.**

The next 2 pages contain definitions for project phases. Please pay particular attention to the start and stop points highlighted. All project costs should be given in U.S. dollars. If you need further assistance in interpreting the intent of a question, please call Steve Thomas CII at (512) 232-3007 (E-mail: sthomas@mail.utexas.edu) or Marvin Oey CII at (512) 232-3051 (E-mail: marvinoey@mail.utexas.edu). Conformance to the instructions and phase definitions is crucial for establishing reliable benchmarks.

Your Company Benchmarking Associate has been provided with a list of projects that were submitted by your company during the previous data collection effort. To maintain the integrity of the database, please ensure that projects that were submitted previously are not reported again.

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. Keep in mind, however, that too many "unknowns" or "not applicables" could render the project unusable for analysis.

This questionnaire should be completed under the direction of the project manager in consultation with colleagues who worked on the project. Again, please carefully review the phase table on the next 2 pages before attempting to provide the requested information.

Definitions are provided in the attached glossary for words and phrases that are both italicized and underlined.

1. Your Company: ____

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 CII personnel identify the questionnaire correctly if clarification of data is needed and to prevent duplicate project entries.)

3. Project Location: Domestic __________________________, USA
State
International _______________________
Country

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

5. Contact Phone No. (   ) ____________ 6. Contact Fax No. (   )

E-mail address ______________________________

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

Electrical (Generating)
Oil Exploration/Production
Oil Refining
Pulp and Paper
Chemical Mfg.
Environmental
Pharmaceuticals Mfg.
Metals Refining/Processing
Microelectronics Mfg.
Consumer Products Mfg.
Natural Gas Processing
Automotive Mfg.
Foods

Infrastructure

______Electrical Distribution
______Highway
______Navigation
______Flood Control
______Rail
______Water/Wastewater
______ Airport
______Tunneling
______Marine Facilities
______Mining

Buildings

Lowrise
Highrise
Warehouse
Hospital
Laboratory
___School
___Prison
___Hotel
___Maintenance Facilities
___Parking Garage
___Retail

______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)______________________________

9. 11a. *Total Project Budget*

- The total project budget amount should correspond to the estimate at the start of detail design including ***contingency***.
- The total project budget amount should include all planned expenses from pre-project planning through startup or to a "ready for use" condition, excluding the ***cost of land***.
- State the project budget in U.S. dollars to the nearest $1000. (You may use a "k" to indicate thousands in lieu of "...,000".)

$________

11b. How much ***contingency*** does this budget contain? (to the nearest $1000. You may use a "k" to indicate thousands in lieu of "...,000".)

$________

12. *Total Actual Project Cost*:

- The total actual project cost should include all actual project costs from pre-project planning through startup or to a "ready for use" condition, excluding the cost of land.
- Actual costs should correspond to those that were part of the budget. For example, if the budget included specific amounts for in-house personnel, then

actual cost should include the actual amounts expended during the project for their salaries, overhead, travel, etc.

- State the project cost in U.S. dollars to the nearest $1000. (You may use a "k" to indicate thousands in lieu of "...,000".)

$________________________

13. Please indicate the budgeted and actual costs by project phase

- Phase budget amounts should correspond to the estimate at the start of detail design.
- Refer to the table on pages 2 and 3 for phase definitions and typical cost elements.
- State the phase costs 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 or Startup please write "NA" for those phases.
- The sum of phase budgets should equal the Total Project Budget and the sum of actual phase costs should equal Total Actual Project Cost from questions 11 & 12 above.

Project Phase	Phase Budget (Including Contingency)	Amount of Contingency in Budget	Actual Phase Cost
Pre-Project Planning	$	$	$
Detail Design	$	$	$
Procurement	$	$	$
Demolition/Abatmnt	$	$	$
Construction	$	$	$
Startup	$	$	$
Totals	$	$	$

14. Planned and Actual Project Schedule

- The dates for the planned schedule should be those in effect at the start of detail design. 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 or Startup please write "NA" for those phases.

Project Phase	Planned Schedule		Actual Schedule	
	Start mm / dd /	Stop mm / dd /	Start mm / dd /	Stop mm / dd /
Pre-Project Planning				
Detail Design				
Procurement				
Demolition/Abatement				
Construction				
Startup				

14a. What percentage of the total engineering workhours for design were completed prior to total project budget authorization? (Write "UNK" in the blank if you don't have this information)

_________ %

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 or obtain original process basis.

Scope Changes include changes in the base scope of work or process basis.

- 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	Net Schedule Impact of Scope Changes
Design			$	$	wks	wks
Procurement			$	$	wks	wks
Demolition/Abatement			$	$	wks	wks
Construction			$	$	wks	wks
Startup			$	$	wks	wks
Totals			$	$	wks	wks

Project Change Management Practices

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

Please check the appropriate response for the questions below. If your company was not involved with the project function(s) in which a practice element is generally used, please write "UNK" for that question.

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 "freezes" 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?

This concludes the questionnaire; please review your responses and ensure you have answered all questions. Thank you for your participation. Please return this questionnaire to your Benchmarking Associate.

Appendix D Analysis of NAVFAC Survey

Analysis of NAVFAC's

Use of the CII Change Management Best Practices

1. The next 2 pages contain definitions for project phases. Please pay particular attention to the start and stop points highlighted. All project costs should be given in U.S. dollars. If you need further assistance in interpreting the intent of a question, please call me, LT Scot Sanders, at (512) 272-8016 or (E-mail: *lt.sanders@mail.utexas.edu*)

2. 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.

3. This questionnaire should be completed under the direction of the project manager in consultation with those who worked on the project. Again, please carefully review the phase table on the next 2 pages before attempting to provide the requested information.

7. This information will remain confidential, and the results as reported will not contain any reference to the specific project.

8. Please mail or email your results to me at the address above or as a secondary address try *ssanders@msn.com*. 11605 Rydalwater Lane Austin, TX 78754. Thank you

Scot Sanders

LT, CEC, USN

Encl (1)

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 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

RESPONDANT DATA

1. Your Base/Unit Name:____________________________

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 CII personnel identify the questionnaire correctly if clarification of data is needed and to prevent duplicate project entries.)

3. Project Location: Domestic __________________________USA
State

International ______________________________
Country

4. Point of Contact: ____

5. Contact Phone No. ___________________________
6. Contact Fax No. __________________________E-mail: _____________________

7. Principal Type of Project:
(Circle 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 Distribution	Lowrise Office (<3 floors)
Oil-Exploration/Production	Highway	High-rise Office (>3 floors)
Oil-Refining	Navigation	Warehouse
Pulp and Paper	Flood Control	Hospital
Chemical Mfg.	Rail	Laboratory
Environmental	Water/Wastewater	School
Pharmaceuticals Mfg	Airport	Prison
Metals Refining/Processing	Tunneling	Hotel
Microelectronics Mfg.	Marine Facilities	Maintenance Facilities
Consumer Products Mfg	Mining	Parking Garage
Natural Gas Processing	Pipeline	Retail
Automotive Mfg.	Gas Distribution	Communications Center
Foods	Telecom, Wide Area Network	
Residential		
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)

1. Please indicate the budgeted and actual costs by project phase.

• Phase budget amounts should correspond to the estimate at the start of detail design. Refer to the table on pages 2 and 3 for phase definitions and typical cost elements.

• State the phase costs 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 or Startup please write "NA" for those phases.

• The total project budget amount should correspond to the estimate at the start of detail design **including contingency.**

• The total project budget amount should include all planned expenses from pre-project planning through startup or to a "ready for use" condition, excluding the **Cost of Land**.

• The total actual project cost should include all actual project costs from pre-project planning through startup or to a "ready for use" condition, excluding the cost of land.

• Actual costs should correspond to those that were part of the budget. For example, if the budget included specific amounts for in-house personnel, then actual cost should include the actual amounts expended during the project for their salaries, overhead, travel, etc.

Project Phase	Phase Budget (Including Contingency)	Amount of Contingency in Budget	Actual Phase Cost
Pre-Project Planning	$	$	$
Detail Design	$	$	$
Procurement	$	$	$
Demolition/Abatement	$	$	$
Construction	$	$	$
Startup	$	$	$
Totals	$	$	$

2. Planned and Actual Project Schedule

- The dates for the planned schedule should be those in effect at the start of detail design. If you cannot provide an exact day for either the planned or actual, estimate to the nearest week in the for example mm/dd/yyyy; for example, 1/8/1998, 2/15/1998, or 3/22/1998.
- 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 or Startup please write "NA" for those phases.

Project Phase	Planned Schedule		Actual Schedule	
	Start mm / dd / yy	Stop mm / dd / yy	Start mm / dd / yy	Stop mm / dd / yy
Pre-Project Planning	/ /	/ /	/ /	/ /
Detail Design	/ /	/ /	/ /	/ /
Demolition/Abatement	/ /	/ /	/ /	/ /
Construction	/ /	/ /	/ /	/ /
Startup	/ /	/ /	/ /	/ /

3. What percentage of the total engineering workhours for design was completed prior to total project budget authorization? (Write "UNK" in the blank if you don't have this information)

______________%

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

__________________%

5. 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. Either the owner or contractor may initiate changes.

Project Development Changes include those changes required to execute the original scope of work or obtain original process basis.

Scope Changes include changes in the base scope of work or process basis.

- 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 "O" 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	Net Schedule Impact of Scope Changes
Design			$	$	wks	wks
Demolition/Abatement			$	$	wks	wks
Construction			$	$	wks	wks
Startup			$	$	wks	wks
Totals			$	$	wks	wks

Project Change Management Practices

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

Please check the appropriate response for the questions below. If your organization was not involved with the project function(s) in which a practice element is generally used, please write "UNK" for that question.

	Yes	No
1. Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?		
2. Was a baseline project scope established early in the project and frozen with changes managed against this base?		
3. Were design "freezes" established and communicated once designs were complete?		
4. Were areas susceptible to change identified and evaluated for risk during review of the project design basis?		
5. Were changes on this project evaluated against the business drivers and success criteria for the project?		
6. Were all changes required to go through a formal change justification procedure?		
7. Was authorization for change mandatory before implementation?		
8. Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?		
9. Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?		
10. Did the project contract address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract?		
11. Was a tolerance level for changes established and communicated to all project participants?		
12. Were all changes processed through one owner representative?		
13. At project closeout, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?		
14. 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?		

- This concludes the questionnaire; please review your responses and ensure you have answered all questions. Thank you for your participation.
- Please return this questionnaire to ***LT Scot Sanders, CEC, USN*** *lt.sanders@mail.utexas.edu* By ***10 June 00***!

Appendix E NAVFAC Performance Factors

Appendix E NAVFAC Performance Factors Database

cii_id	Industry	Nature	costcat	chgindex	schdgrow	schdfact	des_df	pro_df	dmo_df	con_df	stu_df	actual_du	costfact	costgrow
O190	Buildings	Add on	15MM - $50MI	7.14	-0.082	0.918	0.31	-777	-777	0.539	-777	223	0.053	-0.255
O191	Buildings	Grass Roots	50MM - $100M	5.71	1.71	2.71	0.22	0.131	0.643	0.643	0.643	168	0.042	0.042
O192	Buildings	Grass Roots	15MM - $50MI	5.71	0.03	1.03	0.269	0.102	-777	0.405	-777	205	0.043	0.021
O193	Buildings	Grass Roots	< $15MM	5.71	0.109	1.109	0.477	0.047	-777	0.451	-777	193	0.051	0.047
O194	Buildings	Grass Roots	> $100MM	5.71	0.013	0.975	0.25	-777	-777	0.423	0.066	158	0.011	-0.052
O195	Buildings	Grass Roots	< $15MM	6.43	0.318	1.318	0.663	-777	-777	0.286	-777	199	0.117	-0.216
O393	Buildings	Grass Roots	< $15MM	5	0.473	1.069	0.135	0.061	-777	0.493	-777	109	0.208	0.487
O394	Industrial	Modernizatior	< $15MM	5	3.794	4.794	0.321	0.083	-777	0.43	-777	163	0.001	-0.041
O395	Buildings	Grass Roots	15MM - $50MI	2.86	-0.053	0.947	0.25	-777	-777	0.468	-777	179	0	-0.237
O396	nfrastructu	Add on	< $15MM	9.17	0.141	1.141	0.281	-777	-777	0.493	-777	146	0.024	-0.028
O397	Buildings	Grass Roots	< $15MM	9.17	0.075	1.075	0.305	0.04	-777	0.511	-777	201	0.005	-0.089
O398	Buildings	Grass Roots	< $15MM	8.46	-0.041	0.658	0.219	0.08	-777	0.498	0.093	187	0.141	-0.037
O399	Buildings	Grass Roots	< $15MM	7.14	-0.019	0.981	0.164	0.113	0.269	0.269	0.269	153	0.046	0.103
O400	nfrastructu	Modernizatior	< $15MM	6.92	0	0.649	0.155	-777	-777	0.754	-777	277	0.951	0.152
O401	Buildings	Grass Roots	< $15MM	6.43	0.007	0.957	0.113	0.078	-777	0.505	-777	154	0.036	-0.022
O402	Buildings	Grass Roots	< $15MM	7.86	0.167	1.008	0.378	-777	0.109	0.546	-777	119	0.04	-0.014
O403	Buildings	Grass Roots	< $15MM	7.86	0.192	1.183	0.273	-777	-777	0.372	-777	149	0.062	-0.015
O428	Buildings	Grass Roots	< $15MM	6.92	-777	-777	-777	0.26	-777	0.61	0.026	137	0.016	0.104
O429	Industrial	Modernizatior	< $15MM	5	3.794	4.794	0.321	0.083	-777	0.43	-777	163	0.001	-0.041
O430	Buildings	Grass Roots	< $15MM	5	0.473	1.069	0.135	0.061	-777	0.493	-777	109	0.208	0.487
P1	Buildings	Modernizatior	< $15MM	8.57	0	0.9944	0.2377	0	0.0113	0.6906	#####	76	0.0076	0.0290
P2	Buildings	Grass Roots	< $15MM	6.92	0.0799	1.0711	0.2391	0	0	0.7002	#####	75	0.0072	0.0338
P3	Buildings	Modernizatior	< $15MM	7.50	-777	-777	-777	-777	-777	-777	-777	-777	0.0330	0.0195
P4	Buildings	Modernizatior	< $15MM	5.00	0.2041	1.1974	0.1341	0.3883	0.099	0.3775	#####	93	0.0106	0.0107
P5	Buildings	Add on	< $15MM	6.43	0	0.9962	0.2377	0	0.0113	0.6906	#####	76	0.0085	0.0400
P6	Buildings	Grass Roots	15MM - $50MI	10.00	-777	-777	-777	-777	-777	-777	-777	-777	0.4813	-0.2580
P7	Industrial	Grass Roots	< $15MM	8.18	-0.1678	0.8322	0.5645	0	0.2177	0.2177	0	18	0.1108	-0.0610
P8	Buildings	Grass Roots	> $100 MM +	5.45	0	0.9383	0.243	0	0.1084	0.5755	#####	235	0.2544	0.2258
P9	Buildings	Add on	< $15MM	6.43	-0.1245	1.1058	0.360	0.260788	0.004	0.3640	#####	76	0.0138	0.0046
P10	Buildings	Modernizatior	< $15MM	7.14	-0.1699	0.8123	0.000	0	0.092	0.9076	0	43	0.1462	-0.0442
P11	nfrastructu	Add on	< $15MM	9.29	0.1593	1.1465	0.633	0	0	0.3674	0	45	0.0659	0.0833
P12	Buildings	Grass Roots	< $15MM	5.71	-777	-777	-777	-777	-777	-777	-777	52	0.0000	-0.1295
P13	Buildings	Add on	< $15MM	7.86	0.0682	1.0620	0.142	0.1368613	0.109	0.2810	#####	157	0.1123	0.1275
P14	nfrastructu	Modernizatior	< $15MM	9.29	0.1790	1.1512	0.386	0.3064295	0	0.3078	0	104	-0.0087	0.0898
P15	Buildings	Modernizatior	< $15MM	5.71	-0.1291	0.8709	0	0	0.1861	0.7666	#####	45	0.0215	-0.1328

cii_id	constdur	desgrow	progrow	congrow	budgfact	pppbf	desbf	probf	conbf	stubf			projcost	prbudget
O190	132	-0.295	-888	-0.253	0.717	0.001	0.054	-888	0.946	-888			16580000	22260000
O191	108	-0.029	-888	0.048	0.999	-888	0.066	-888	0.934	-888			78170000	75000000
O192	107	-0.059	-888	0.027	0.978	-888	0.068	-888	0.932	-888			29153000	28565000
O193	87	0.173	-888	0.035	0.99	-888	0.096	-888	0.904	-888			7494000	7156000
O194	83	0	-888	-0.055	0.937	0.003	0.041	-888	0.956	-888			272356000	287425000
O195	57	-0.543	-888	-0.051	0.718	-888	0.037	-888	0.963	-888			8547000	10900000
O393	73	-888	-888	0.268	1.136	0.055	0.092	-888	0.853	-888			4164000	2800000
O394	83	-888	-888	-0.041	0.958	0.028	0.101	-888	1	-888			4048000	4223000
O395	103	-0.28	-888	-0.233	0.763	0	0.088	-888	0.911	-888			17846000	23398000
O396	72	-0.048	-888	-0.026	0.949	-888	0.088	-888	0.912	-888			2915000	3000000
O397	114	-0.816	-0.196	-0.02	0.907	0.003	0.017	0.001	0.978	-888			13828000	15180000
O398	118	-888	-888	-888	0.848	-888	-888	-888	-888	-888			3947000	4100000
O399	74	0.239	-888	0.087	1.05	-888	0.118	-888	0.882	-888			4190176	3800000
O400	214	0.04	-888	0.165	0.55	0.004	0.091	-888	0.905	-888			4853140	4214500
O401	103	-888	-888	-0.021	0.945	0.038	0.062	-888	0.899	-888			6687000	6840000
O402	65	0.261	-888	0.023	0.949	-888	0.102	-888	0.861	-888			5464000	5540000
O403	86	0	-888	-0.017	0.928	0.024	0.077	-888	0.9	-888			3781000	3839000
O428	94	-888	-888	0.104	1.085	-888	-888	-888	1	-888			8202000	7429000
O429	83	-888	-888	-0.041	0.958	0.028	0.101	-888	1	-888			4048000	4223000
O430	73	-888	-888	0.268	1.136	0.055	0.092	-888	0.853	-888			4164000	2800000
P1	52	0.8680	-888	0	1.021	0.0095	0.0606	0	0.8971	0.0048			$2,101,264	$2,042,103
P2	53	0.5518	-888	0	1.026	0	0.0920	0	0.8639	0.0048			$1,655,206	$1,601,045
P3	-777	-888	-888	0.019504	0.986	0	0	0	1	0			$5,750,000	$5,640,000
P4	35	0	-888	0.0125	1.000	0.0086	0.09010	0	0.8625	0.0028			$3,030,000	$2,997,800
P5	52	1	-888	0	1.031	0.0089	0.0769	0	0.8673	0.0045			$2,240,206	$2,154,045
P6	-777	-0.7058	-888	-0.2325	0.547	0	0.0214	0	0.9786	0			$35,765,000	$48,200,000
P7	4	0	-0.0087	-0.0751	0.850	0	0.0779	0.0954	0.7642	0			$240,000	$255,600
P8	135	0	-0.1429	1.5397	0.076	0.0053	0.0451	0.0263	0.7018	0.0211			$199,500,000	$162,750,000
P9	28	0.0169	0	0	0.991	0.0092	0.2752	0.0459	0.6147	0.0092			$218,000	$217,000
P10	39	0	-888	0.3318	0.839	0	0.0990	0.0000	0.9010	0			$707,266	$740,000
P11	16	0.3077	-888	0.0714	1.011	0.0037	0.0623	0	0.9341	0			$273,000	$252,000
P12	52	-888	-888	-0.1295	0.870	0	0	0	1	0			$14,624	$16,800
P13	44	-888	0	0.1404	1.001	0.0009	0	0.0043	0.8826	0.0913			$5,750,000	$5,100,000
P14	32	0.0385	-888	0.0930	1.100	0	0.0543	0	0.9457	0			$1,492,000	$1,369,000
P15	35	-888	-888	-0.0867	0.851	0	0	0	0.8965	0.0080			$2,506,108	$2,890,000

Appendix E Average NAVFAC Performance Metric Values

by group

Size	chgindex	costfact	costgrow	schdgrow	budgfact	schdfact	actual_dur	constdur	projcost	prbudget
<15	7.004	0.087	0.034	-82.9	0.953	-82.1	91	38	4,011,071	3,975,710
15-50	6.428	0.144	-0.182	-194.3	0.751	-193.5	-43	-109	24,836,000	30,605,750
50-100	5.710	0.042	0.042	1.7	0.999	2.7	168	108	78,170,000	75,000,000
>100	5.582	0.133	0.087	0.007	0.507	0.957	196	109	235,928,000	225,087,500
Nature	**chgindex**	**costfact**	**costgrow**	**schdgrow**	budgfact	schdfact	actual_dur	constdur	projcost	prbudget
Add-on	7.72	0.05	0.00	0.03	0.95	1.06	120.36	57.40	4,662,701	5,497,174
Grass roots	6.61	0.09	0.02	-116.4	0.89	-115.6	101.1	40.6	35,258,400	34,879,772
Modernization	6.68	0.13	0.00	-85.5	0.92	-84.6	20.8	-22.6	3,170,642	3,148,823
Industry Group	**chgindex**	**costfact**	**costgrow**	**schdgrow**	budgfact	schdfact	actual_dur	constdur	projcost	prbudget
Bldgs	6.64	0.08	0.01	-110.9	0.90	-110.1	72	16	26,564,673	26,477,885
Hvy Ind	6.06	0.04	-0.05	2.47	0.92	3.47	115	57	2,778,667	2,900,533
Infrastructure	8.67	0.26	0.07	0.12	0.90	1.02	143	84	2,383,285	2,208,875

Appendix F Descriptive Statistics

Appendix F-1

NAVFAC Projects

Decriptive Statisitics

Metric	***chgindex***	***costfact***	***costgrow***	***schdgrow***	*budgfact*
Mean (avg)	6.8197	0.0949	0.01241	-88.4799921	0.9058
Standard Error	0.2705	0.0301	0.02744	42.41594516	0.0339
Median	6.92	0.04	0.00461	0.013	0.958
Mode	5	0.208	0.487	0	1.136
Standard Deviation	1.6002	0.1780	0.16232	250.9361156	0.200
Sample Variance	2.5606	0.0317	0.02635	62968.93413	0.040
Kurtosis	-0.2097	16.3375	2.903	4.689132566	7.990
Skewness	0.0082	3.7660	1.13404	-2.53455186	-2.429
Range	7.14	0.959713	0.74499	780.794	1.060
Minimum	2.86	-0.008713	-0.25799	-777	0.076
Maximum	10	0.951	0.487	3.794	1.136
Sum	238.6880	3.3206	0.43447	-3096.79972	31.7023
Count	35	35	35	35	35
Confidence Level(95.0%)	0.5497	0.0612	0.05576	86.19951501	0.06885

Metric	*schdfact*	*actual_dur*	*constdur*	*projcost*	*prbudget*
Mean	-87.6410	83.7837	27.2204	$21,762,285	$21,683,368
Standard Error	42.4676	37.7866	34.6223	$9,479,787	$9,312,426
Median	1.008	146	73	$4,164,000	$4,214,500
Mode	-777	109	83	$4,164,000	$2,800,000
Standard Deviation	251.24	223.55	204.83	$56,083,176	$55,093,054
Sample Variance	63122.50	49973.95	41954.60	3.14532E+15	3.03524E+15
Kurtosis	4.69	12.19	13.43	14.29	17.27
Skewness	-2.53	-3.49	-3.73	3.78	4.02
Range	781.794	1054	991	$272,341,376	$287,408,200
Minimum	-777	-777	-777	14624	16800
Maximum	4.794	277	214	$272,356,000	$287,425,000
Sum	-3067.44	2932.43	952.71	$761,679,990	$758,917,893
Count	35	35	35	35	35
Confidence Level(95.0%)	86.30	76.79	70.36	$19,265,232	$18,925,114

Appendix F-2

Other CII Projects

Decriptive Statisitics

	chgindex	*costfact*	*costgrow*	*budgfact*	*schdgrow*	*schdfact*	*actual_dur*	*constdur*
Mean	7.6829	0.1050	0.1221	0.9539	0.1046	1.0140	94.276	60.468
Standard Error	0.0728	0.0114	0.0555	0.0052	0.0219	0.0209	2.696	2.117
Median	7.86	0.0575	0.003	0.967	0.01	1	84	54
Mode	10	0	0	1	0	1	87	22
Standard Deviation	1.7825	0.2604	1.5715	0.1467	0.6016	0.5751	50.5084	39.5
Sample Variance	3.1773	0.0678	2.4697	0.0215	0.3619	0.3307	########	1560.25
Kurtosis	0.1633	155.9524	735.0954	5.7015	468.1516	574.3479	1.8783	2.7842
Skewness	-0.6901	10.4247	26.5802	0.1518	19.5345	22.5053	1.2750	1.417165
Range	10	5.177	44.411	1.687	15.294	15.331	290	251
Minimum	0	-0.748	-0.795	0.161	-0.544	0.419	15	1
Maximum	10	4.429	43.616	1.848	14.75	15.75	305	252
Sum	4609.76	55.243	97.962	765.062	78.839	764.534	33091	21043
Count	600	526	802	802	754	754	351	348
Confidence Level(90.0%)	0.11988	0.01871	0.09138	0.00853	0.03608	0.03449	5.302	4.165

Descriptive Statistics	*projcost*	*prbudget*	*congrow*	*desbf*	*conbf*	*overall*	*des_df*	*con_df*
Mean	62,852,152	68,257,849	0.0145	0.13839	0.513565598	129.9375	0.419748	0.476415
Standard Error	8,025,272	9,127,911	0.0179	0.00502	0.011068706	3.682363608	0.009715	0.01121
Median	17,750,000	18,300,000	-0.015	0.1225	0.472	112.5	0.391	0.46
Mode	8,700,000	12,000,000	0	0.063	0.365	83	0.25	1
Standard Deviation	155,615,799	177,231,979	0.327388591	0.0921	0.2050	69.0873	0.1783	0.2088
Sample Variance	2.42163E+16	3.14112E+16	0.107183289	0.0085	0.0420	4773.0502	0.0318	0.0436
Kurtosis	41.0845	48.0027	29.0263	17.1110	-0.3022	1.4574	0.4604	-0.0591
Skewness	5.7865	6.2144	3.8604	2.4796	0.6156	1.1541	0.7444	0.5116
Range	1537062600	1759972600	3.848	0.936	0.962	391	0.918	0.958
Minimum	27400	27400	-0.879	0.01	0.038	17	0.082	0.042
Maximum	1537090000	1760000000	2.969	0.946	1	408	1	1
Sum	23632409022	25733209217	4.878	46.498	176.153	45738	141.455	165.316
Count	376	377	336	336	343	352	337	347
Confidence Level(95.0%)	15780167.516	17948131.420	0.035	0.0099	0.0218	7.2423	0.0191	0.0220

APPENDIX F-3

Other Public Projects

Descriptive statistics

chgindex		*costfact*		*costgrow*		*budgfact*		*schdgrow*	
Mean	6.648125	Mean	0.11878	Mean	0.053667	Mean	0.9502	Mean	0.525099
Standard Error	0.332836	Standard Error	0.025794	Standard Error	0.021141	Standard Error	0.019995	Standard Error	0.17037
Median	7.14	Median	0.0765	Median	0.01	Median	0.966	Median	0.178
Mode	7.86	Mode	0	Mode	0	Mode	1	Mode	0
Standard Deviation	2.662686	Standard Deviatioi	0.182391	Standard Deviation	0.183088	Standard Devia	0.173162	Standard Deviatioi	1.43556
Sample Variance	7.089895	Sample Variance	0.033266	Sample Variance	0.033521	Sample Varianc	0.029985	Sample Variance	2.060832
Kurtosis	0.27013	Kurtosis	9.051378	Kurtosis	4.271907	Kurtosis	3.087489	Kurtosis	30.64439
Skewness	-0.93558	Skewness	2.671293	Skewness	1.176181	Skewness	-0.14919	Skewness	5.104825
Range	10	Range	1.073	Range	1.264	Range	1.069	Range	10.958
Minimum	0	Minimum	-0.224	Minimum	-0.527	Minimum	0.371	Minimum	-0.791
Maximum	10	Maximum	0.849	Maximum	0.737	Maximum	1.44	Maximum	10.167
Sum	425.48	Sum	5.939	Sum	4.025	Sum	71.265	Sum	37.282
Count	64	Count	50	Count	75	Count	75	Count	71
Confidence Level(95.0%)	0.665119	Confidence Level(	0.051835	Confidence Level(9:	0.042125	Confidence Lev	0.039841	Confidence Level(	0.339791

schdfact		*actual_dur*		*constdur*		*projcost*		*prbudget*	
Mean	1.381282	Mean	164.9487	Mean	93.75	Mean	16256051	Mean	15638012
Standard Error	0.16689	Standard Error	9.996068	Standard Error	6.726672	Standard Error	2226467	Standard Error	2100735
Median	1.02	Median	141	Median	82.5	Median	7274000	Median	7165500
Mode	1	Mode	139	Mode	153	Mode	6640000	Mode	46085000
Standard Deviation	1.406243	Standard Deviatioi	88.28288	Standard Deviation	58.64177	Standard Devia	19281768	Standard Deviatioi	18313786
Sample Variance	1.977519	Sample Variance	7793.867	Sample Variance	3438.857	Sample Varianc	3.72E+14	Sample Variance	3.35E+14
Kurtosis	34.71384	Kurtosis	0.12494	Kurtosis	0.263465	Kurtosis	2.175049	Kurtosis	2.625328
Skewness	5.419937	Skewness	0.741813	Skewness	0.701365	Skewness	1.767115	Skewness	1.795384
Range	10.958	Range	390	Range	245	Range	78879000	Range	83409000
Minimum	0.209	Minimum	17	Minimum	5	Minimum	591000	Minimum	591000
Maximum	11.167	Maximum	407	Maximum	250	Maximum	79470000	Maximum	84000000
Sum	98.071	Sum	12866	Sum	7125	Sum	1.22E+09	Sum	1.19E+09
Count	71	Count	78	Count	76	Count	75	Count	76
Confidence Level(95.0%)	0.332852	Confidence Level(	19.90474	Confidence Level(9:	13.40022	Confidence Lev	4436333	Confidence Level(	4184880

Appendix G ANOVA Tests

Appendix G ANOVA Tests

For each Performance Factor

Anova: Single Factor

SUMMARY **Change Index**

Groups	Count	Sum	Average	Variance
CII	294	2289.2	7.7863605	2.957955
Navy	35	238.69	6.8196575	2.56064
Public	65	431.19	6.6336923	6.992655

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	89.049	2	44.524393	12.42373	5.87E-06	3.018798
Within Groups	1401.3	391	3.5838171			
Total	1490.3	393				

Anova: Single Factor

SUMMARY **Cost grow**

Groups	Count	Sum	Average	Variance
CII	376	-12.72	-0.033832	0.019819
Other Public	76	4.136	0.0544211	0.033118
Navy	20	0.396	0.0198	0.03686

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.5212	2	0.2606166	11.51332	1.31E-05	3.014947
Within Groups	10.616	469	0.0226361			
Total	11.138	471				

Anova: Single Factor **Sched grow**

SUMMARY

Groups	Count	Sum	Average	Variance
CII	342	40.822	0.1193626	0.697802
Other Public	72	37.282	0.5178056	2.035636
Navy	19	11.101	0.5842632	1.43836

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12.286	2	6.1428394	6.46819	0.001707	3.016694
Within Groups	408.37	430	0.9496999			
Total	420.66	432				

see next page for breakouts by groups

Appendix G ANOVA

ANOVAs: Grouped by Industry

Anova: Single Factor		CHNG INDEX				
SUMMARY		**Buildings**				
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	21	147.3	7.0119	2.9		
OP	51	326.7	6.4055	7.9		
N	28	185.8	6.6373	2.2		
ANOVA						
Source of V.	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Gr	5.531	2	2.7655	0.5	0.594	3.09
Within Grou	512.7	97	5.2853			
Total	518.2	99				

Anova: Single Factor		CHNGINDX				
SUMMARY		**Industrial**				
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	212	1686	7.951	3		
OP	10	78.08	7.808	3.6		
N	3	18.18	6.0606	3.4		
ANOVA						
Source of V.	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Gr	10.7	2	5.3508	1.8	0.174	3.037
Within Grou	674.1	222	3.0364			
Total	684.8	224				

Anova: Single Factor		**Infrastructure**				
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	26	193.2	7.4292	2.1		
Column 2	4	26.43	6.6075	1.5		
Column 3	4	34.66	8.6654	1.4		
ANOVA						
Source of V.	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Gr	8.732	2	4.3661	2.2	0.126	3.305
Within Grou	60.99	31	1.9675			
Total	69.73	33				

Grouped by Nature

Anova: Single Factor		CHNGIDX				
SUMMARY		**Grass-roots**				
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	85	661.4	7.7812	2.57		
OP	22	159	7.2255	5.07		
N	20	132.2	6.6122	2.75		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24.143	2	12.071	4	0.021	3.07
Within Groups	374.3	124	3.0185			
Total	398.44	126				

Anova: Single Factor		CHNGIDX				
SUMMARY		**ADD-ON**				
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	88	685.5	7.7898	3.75		
OP	10	61.31	6.131	7.77		
N	6	46.31	7.7183	1.65		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-valu*	*F crit*
Between Groups	24.762	2	12.381	3.09	0.05	3.09
Within Groups	404.15	101	4.0015			
Total	428.91	103				

Anova: Single Factor		CHNG INDX				
SUMMARY		**MODERNIZATION**				
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	121	942.3	7.7875	2.71		
OP	33	210.9	6.3915	8.09		
N	9	60.13	6.6816	2.59		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-valu*	*F crit*
Between Groups	56.065	2	28.033	7.42	8E-04	3.05
Within Groups	604.77	160	3.7798			
Total	660.84	162				

Grouped By Size

Anova: Single Facto		Chng Indx				
SUMMARY		**<15M**				
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	143	1098	7.6759	3.2		
Other Public	49	322.7	6.5861	8		
Navy	29	204	7.0332	2		
ANOVA						
Source of V.	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Gr	46.69	2	23.347	5.7	0.004	3.037
Within Grou	888	218	4.0734			
Total	934.7	220				

Anova: Single Facto		Chng idx				
SUMMARY		**15-50**				
Groups	*Count*	*Sum*	*Average*	*Variance*		
CII	82	633.7	7.7276	3.4		
Other Public	10	77.03	7.703	3.3		
Navy	3	15.71	5.2367	4.7		
ANOVA						
Source of V.	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Gr	17.99	2	8.9963	2.6	0.079	3.095
Within Grou	317.7	92	3.4534			
Total	335.7	94				

Chng idx
>50 M

N.A.

Appendix G ANOVA Tests

ANOVAs: **Size: All less than $15M**

Sub divided by: Grouped by Industry

Anova: Single Factor — **Chng Indx**
SUMMARY — **Building <15M**

Groups	Count	Sum	Average	/ariance
CII	15	104.8	6.9847	3.411
Other Public	39	241.8	6.1997	8.859
Navy	21	143.3	6.8219	1.472

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9.144	2	4.572	0.795	0.4553	3.12
Within Groups	413.8	72	5.7479			
Total	423	74				

Anova: Single Factor — **Chng Indx**
SUMMARY — **Industrial <15M**

Groups	Count	Sum	Average	/ariance
CII	98	774	7.8979	3.11
O	8	68.79	8.5988	1.062
N	3	18.18	6.0606	3.375

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	14.06	2	7.0282	2.358	0.0995	3.08
Within Groups	315.9	106	2.98			
Total	329.9	108				

Anova: Single Factor
SUMMARY — **Infrastructure <15M**

Groups	Count	Sum	Average	/ariance
CII	29	208.9	7.2034	2.649
O	4	29.29	7.3214	3.19
N	4	35.38	8.8439	1.78

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9.483	2	4.7416	1.81	0.1791	3.28
Within Groups	89.09	34	2.6202			
Total	98.57	36				

Grouped by Nature

Anova: Single Factor — CHNGIDX
SUMMARY — Grass-roots <15M

Groups	Count	Sum	Average	Variance
CII	23	175.82	7.6443	3.1944
OP	11	79.07	7.1882	6.9058
N	14	96.799	6.9142	1.6625

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.9136	2	2.4568	0.6869	0.5083	3.2043
Within Groups	160.95	45	3.5766			
Total	165.86	47				

Anova: Single Factor — Change Index
SUMMARY — Moderization <15M

Groups	Count	Sum	Average	Variance
CII	77	591.25	7.6786	2.8419
OP	31	198.77	6.4119	8.4139
N	9	60.134	6.6816	2.5889

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38.793	2	19.396	4.5208	0.0129	3.0759
Within Groups	489.11	114	4.2904			
Total	527.9	116				

Anova: Single Factor — CHNGIDX
SUMMARY — Add-on <15M

Groups	Count	Sum	Average	Variance
CII	43	330.59	7.6881	3.8383
OP	8	52.74	6.5925	8.6234
N	5	39.17	7.834	1.9608

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.5567	2	4.2783	0.9884	0.3789	3.1716
Within Groups	229.42	53	4.3286			
Total	237.97	55				

Appendix H Regressions for Table 5.11

Appendix H Regressions for Table 5.11

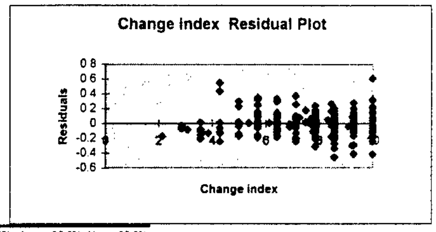
OtherCII
Change index vs cost Growth

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.234496
R Square	0.054988
Adjusted R Square	0.051752
Standard Error	0.143932
Observations	294

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.351992	0.351992	16.99088384	4.89898E-05
Residual	292	6.049227	0.020717		
Total	293	6.401219			



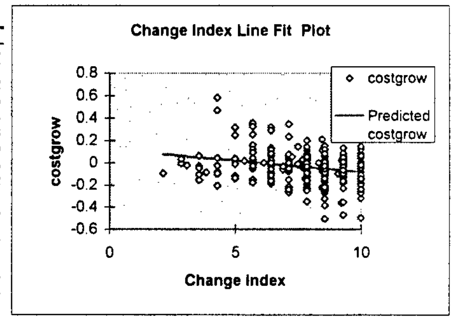
	Coefficients	Standard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.122183	0.038983	3.134274	0.0018981	0.045460001	0.198906	0.04546	0.198906
chgindex	-0.02015	0.004889	-4.122	4.89898E-05	-0.029775203	-0.01053	-0.02978	-0.01053

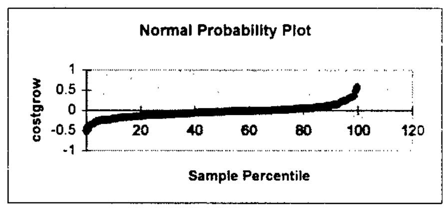
RESIDUAL OUTPUT

Observation	Predicted cos	Residuals	Standard Residuals
1	0.079056	-0.17306	-1.2044
2	0.064546	-0.06955	-0.48401
3	0.064546	-0.03155	-0.21954
4	0.060112	-0.08211	-0.57147
5	0.050237	-0.20424	-1.42141
6	0.050237	-0.15724	-1.09431
7	0.050237	-0.09824	-0.68369
8	0.050237	-0.08024	-0.55842
9	0.050237	0.012763	0.088825
10	0.044594	-0.13159	-0.91584
11	0.035727	-0.24173	-1.68232
12	0.035727	-0.13673	-0.95156
13	0.035727	-0.13173	-0.91677
14	0.035727	-0.11573	-0.80541
15	0.035727	-0.06273	-0.43655
16	0.035727	0.008273	0.057577
17	0.035727	0.434273	3.022363
18	0.035727	0.546273	3.801838
19	0.021418	-0.16542	-1.15125
20	0.021418	-0.16042	-1.11645
21	0.021418	-0.13842	-0.96334
22	0.021418	-0.03342	-0.23258
23	0.021418	0.016582	0.115401
24	0.021418	0.228582	1.590834
25	0.021418	0.296582	2.064087
26	0.01376	0.00324	0.022546
27	0.01376	0.00324	0.022546
28	0.00711	-0.18511	-1.28829
29	0.00711	-0.15911	-1.10734
30	0.00711	-0.06211	-0.43226
31	0.00711	-0.05111	-0.3557
32	0.00711	-0.03611	-0.25131
33	0.00711	-0.02411	-0.1678
34	0.00711	-0.02311	-0.16084
35	0.00711	-0.01211	-0.08428
36	0.00711	-0.00711	-0.04948
37	0.00711	-0.00611	-0.04252
38	0.00711	0.02089	0.145386
39	0.00711	0.03489	0.242821
40	0.00711	0.08589	0.59776

PROBABILITY OUTPUT

Percentile	costgrow
0.170068027	-0.505
0.510204082	-0.497
0.850340136	-0.472
1.19047619	-0.385
1.530612245	-0.363
1.870748299	-0.356
2.210884354	-0.349
2.551020408	-0.325
2.891156463	-0.322
3.231292517	-0.321
3.571428571	-0.276
3.911564626	-0.27
4.25170068	-0.267
4.591836735	-0.264
4.931972789	-0.25
5.272108844	-0.25
5.612244898	-0.248
5.952380952	-0.24
6.292517007	-0.238
6.632653061	-0.236
6.972789116	-0.235
7.31292517	-0.234
7.653061224	-0.231
7.993197279	-0.23
8.333333333	-0.229
8.673469388	-0.225
9.013605442	-0.223
9.353741497	-0.218
9.693877551	-0.216
10.03401361	-0.206
10.37414966	-0.206
10.71428571	-0.2
11.05442177	-0.195
11.39455782	-0.19
11.73469388	-0.188
12.07482993	-0.185
12.41496599	-0.182
12.75510204	-0.181
13.0952381	-0.178
13.43537415	-0.173





Appendix H Regressions for table 5.11

SUMMARY OUTPUT

OtherCII

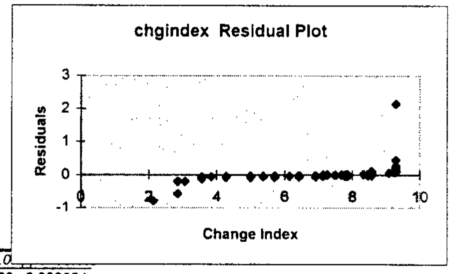
Change index vs cost factor

Regression Statistics	
Multiple R	0.082912
R Square	0.006874
Adjusted R Square	0.002575
Standard Error	0.168322
Observations	233

ANOVA

	df	SS	MS	F	ignificance F
Regression	1	0.045302	0.045302	1.598962	0.207325
Residual	231	6.544756	0.028332		
Total	232	6.590058			

	Coefficient:	'andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0	
Intercept	0.120943	0.050623	2.389108	0.017693	0.021202	0.220684	0.021202	0.220684
chgindex	-0.00805	0.006364	-1.2645	0.207325	-0.02059	0.004492	-0.02059	0.004492

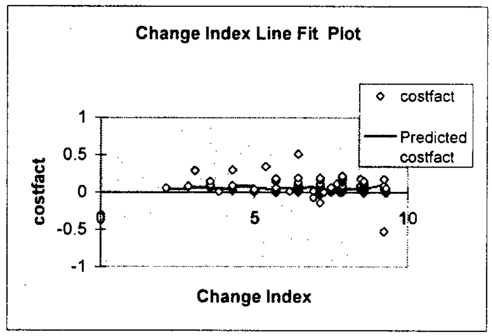


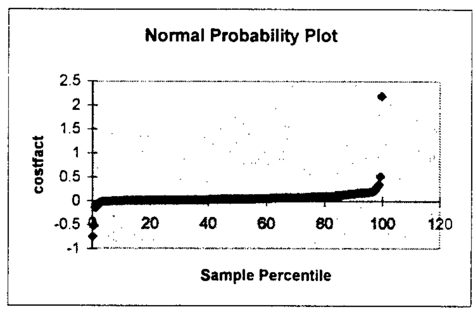
RESIDUAL OUTPUT

Observation	dicted cost	Residuals	dard Residuals
1	0.040468	-0.78847	-4.69441
2	0.046664	-0.57266	-3.40955
3	0.063484	-0.20448	-1.21746
4	0.063484	-0.20248	-1.20555
5	0.065254	-0.13525	-0.80528
6	0.040468	-0.09247	-0.55054
7	0.040468	-0.07847	-0.46718
8	0.063484	-0.09748	-0.5804
9	0.046181	-0.06018	-0.35831
10	0.051976	-0.06398	-0.3809
11	0.046181	-0.05818	-0.3464
12	0.063484	-0.07348	-0.43751
13	0.046181	-0.05618	-0.33449
14	0.074992	-0.08399	-0.50007
15	0.040468	-0.04947	-0.29452
16	0.046181	-0.05118	-0.30473
17	0.057689	-0.05869	-0.34943
18	0.080705	-0.08071	-0.48051
19	0.080705	-0.08071	-0.48051
20	0.069197	-0.0692	-0.41199
21	0.063484	-0.06348	-0.37797
22	0.062437	-0.06244	-0.37174
23	0.058333	-0.05833	-0.34731
24	0.057689	-0.05769	-0.34347
25	0.040468	-0.04047	-0.24094
26	0.060586	-0.05959	-0.35477
27	0.046181	-0.04518	-0.269
28	0.040468	-0.03947	-0.23498
29	0.040468	-0.03947	-0.23498
30	0.069197	-0.0672	-0.40008
31	0.058333	-0.05633	-0.3354
32	0.046181	-0.04318	-0.25709
33	0.057689	-0.05369	-0.31966
34	0.057689	-0.05369	-0.31966
35	0.051976	-0.04798	-0.28564
36	0.080705	-0.07571	-0.45074

PROBABILITY OUTPUT

Percentile	costfact
0.214592	-0.748
0.643777	-0.526
1.072961	-0.141
1.502146	-0.139
1.93133	-0.07
2.360515	-0.052
2.7897	-0.038
3.218884	-0.034
3.648069	-0.014
4.077253	-0.012
4.506438	-0.012
4.935622	-0.01
5.364807	-0.01
5.793991	-0.009
6.223176	-0.009
6.652361	-0.005
7.081545	-0.001
7.51073	0
7.939914	0
8.369099	0
8.798283	0
9.227468	0
9.656652	0
10.08584	0
10.51502	0
10.94421	0.001
11.37339	0.001
11.80258	0.001
12.23176	0.001
12.66094	0.002
13.09013	0.002
13.51931	0.003
13.9485	0.004
14.37768	0.004
14.80687	0.004
15.23605	0.005





Appendix H Regressions for Table 5.11

OtherCII

Change index vs Schedule Growth

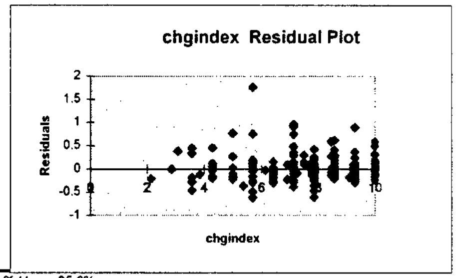
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.162204
R Square	**0.02631**
Adjusted R Square	0.022636
Standard Error	0.248824
Observations	267

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.443334	0.443334	**7.160537**	**0.007917**
Residual	265	16.40707	0.061913		
Total	266	16.8504			

	Coefficients	*Standard Er*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	**0.265109**	0.070203	3.776297	0.000197	0.126881	0.403336	0.126881	0.403336
chgindex	**-0.02352**	0.008788	-2.67592	0.007917	-0.04082	-0.00621	-0.04082	-0.00621

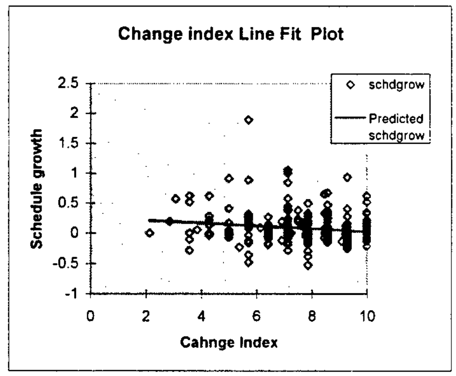


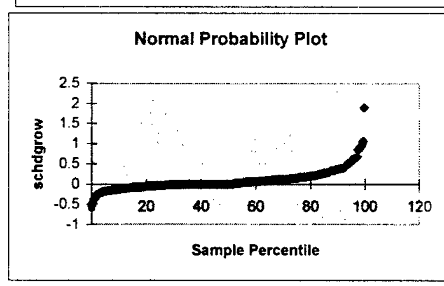
RESIDUAL OUTPUT

Observation	*licted schd*	*Residuals*	*dard Residuals*
1	0.080263	-0.60726	-2.44513
2	0.130825	-0.61283	-2.46753
3	0.080263	-0.46726	-1.88143
4	0.130825	-0.48883	-1.96824
5	0.080263	-0.37426	-1.50696
6	0.097196	-0.3832	-1.54293
7	0.181152	-0.46515	-1.87293
8	0.046634	-0.29663	-1.19439
9	0.138586	-0.36859	-1.4841
10	0.046634	-0.26363	-1.06152
11	0.029937	-0.24294	-0.97818
12	0.097196	-0.2882	-1.16041
13	0.046634	-0.23563	-0.94877
14	0.113893	-0.29989	-1.20751
15	0.080263	-0.25726	-1.03587
16	0.113893	-0.28389	-1.14309
17	0.046634	-0.21563	-0.86824
18	0.130825	-0.29383	-1.18308
19	0.046634	-0.20963	-0.84409
20	0.080263	-0.24026	-0.96742
21	0.063566	-0.21457	-0.86395
22	0.063566	-0.21357	-0.85992
23	0.063566	-0.21257	-0.85589
24	0.097196	-0.2442	-0.98325
25	0.051337	-0.18634	-0.75028
26	0.029937	-0.16294	-0.65606
27	0.063566	-0.19157	-0.77134
28	0.130825	-0.25583	-1.03008
29	0.080263	-0.20526	-0.82649
30	0.10237	-0.22337	-0.89939
31	0.046634	-0.16463	-0.66289
32	0.046634	-0.15763	-0.63471
33	0.063566	-0.17157	-0.69081
34	0.046634	-0.15363	-0.6186
35	0.181152	-0.28415	-1.14413
36	0.029937	-0.12994	-0.52319
37	0.063566	-0.16157	-0.65054
38	0.080263	-0.17426	-0.70167
39	0.029937	-0.11994	-0.48292
40	0.113893	-0.20289	-0.81694
41	0.063566	-0.15157	-0.61028
42	0.029937	-0.11494	-0.46279
43	0.097196	-0.1772	-0.71347
44	0.080263	-0.15726	-0.63322
45	0.066153	-0.14315	-0.5764

PROBABILITY OUTPUT

Percentile	*schdgrow*
0.187266	-0.527
0.561798	-0.482
0.93633	-0.387
1.310861	-0.358
1.685393	-0.294
2.059925	-0.286
2.434457	-0.284
2.808989	-0.25
3.183521	-0.23
3.558052	-0.217
3.932584	-0.213
4.307116	-0.191
4.681648	-0.189
5.05618	-0.186
5.430712	-0.177
5.805243	-0.17
6.179775	-0.169
6.554307	-0.163
6.928839	-0.163
7.303371	-0.16
7.677903	-0.151
8.052434	-0.15
8.426966	-0.149
8 801498	-0.147
9.17603	-0.135
9.550562	-0.133
9.925094	-0.128
10.29963	-0.125
10.67416	-0.125
11.04869	-0.121
11.42322	-0.118
11.79775	-0.111
12.17228	-0.108
12.54682	-0.107
12.92135	-0.103
13.29588	-0.1
13.67041	-0.098
14.04494	-0.094
14.41948	-0.09
14.79401	-0.089
15.16854	-0.088
15.54307	-0.085
15.9176	-0.08
16.29213	-0.077
16.66667	-0.077





Appendix H Regressions for table 5.11

Other Public

Change index vs Cost growth

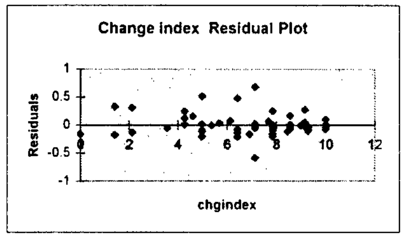
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.200696
R Square	0.040279
Adjusted R Square	0.024013
Standard Error	0.193508
Observations	61

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.092722	0.092722	2.476202	0.120929
Residual	59	2.209272	0.037445		
Total	60	2.301994			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.162568	0.066993	2.426653	0.018313	0.028516	0.29662	0.028516	0.29662
chgindex	-0.01465	0.009311	-1.5736	0.120929	-0.03328	0.003979	-0.03328	0.003979

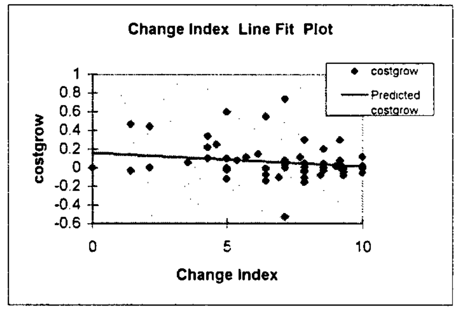


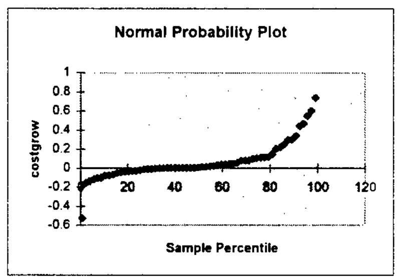
RESIDUAL OUTPUT

Observation	*Predicted cos*	*Residuals*	*Standard Residuals*
1	0.162568	-0.16257	-0.8472
2	0.162568	-0.16257	-0.8472
3	0.162568	-0.16257	-0.8472
4	0.141616	-0.17562	-0.9152
5	0.141616	0.325384	1.695694
6	0.131213	-0.13021	-0.67859
7	0.131213	0.308787	1.609199
8	0.110261	-0.05626	-0.2932
9	0.099712	0.003288	0.017133
10	0.099712	0.120288	0.626862
11	0.099712	0.239288	1.247014
12	0.094877	0.155123	0.8084
13	0.08931	-0.20931	-1.09079
14	0.08931	-0.11331	-0.5905
15	0.08931	-0.08931	-0.46542
16	0.08931	0.00869	0.045288
17	0.08931	0.50969	2.656179
18	0.083742	-0.00374	-0.0195
19	0.078907	0.032093	0.167248
20	0.07246	0.07354	0.383242
21	0.068358	-0.21036	-1.09625
22	0.068358	-0.14036	-0.73146
23	0.068358	-0.08036	-0.41877
24	0.068358	-0.07436	-0.38751
25	0.068358	0.478642	2.494376
26	0.061179	-0.16418	-0.85559
27	0.057955	-0.58496	-3.04841
28	0.057955	-0.05796	-0.30203
29	0.057955	-0.05796	-0.30203
30	0.057955	-0.02496	-0.13005
31	0.057955	-0.01996	-0.10399
32	0.057955	0.019045	0.099249
33	0.057955	0.679045	3.538746
34	0.049897	0.064103	0.334064
35	0.047406	-0.20341	-1.06002
36	0.047406	-0.15541	-0.80988
37	0.047406	-0.08941	-0.46593
38	0.047406	-0.08041	-0.41903
39	0.047406	-0.03741	-0.19494
40	0.047406	0.000594	0.003095
41	0.047406	0.249594	1.300723
42	0.038615	-0.11762	-0.61293
43	0.037003	-0.067	-0.34918
44	0.037003	-0.037	-0.19284
45	0.037003	0.007997	0.041673
46	0.037003	0.165997	0.865067
47	0.030703	-0.0127	-0.0662
48	0.028213	-0.03021	-0.15745
49	0.028213	0.008787	0.045795
50	0.028213	0.048787	0.254249
51	0.028213	0.270787	1.411171
52	0.026454	-0.10745	-0.55998
53	0.026454	-0.07545	-0.39322
54	0.026454	-0.04145	-0.21603
55	0.026454	-0.02745	-0.14307
56	0.016052	-0.07205	-0.37549
57	0.016052	-0.02605	-0.13576
58	0.016052	-0.00905	-0.04717
59	0.016052	-0.00605	-0.03154
60	0.016052	0.006948	0.03621
61	0.016052	0.099948	0.520866

PROBABILITY OUTPUT

Percentile	*costgrow*
0.819672	-0.527
2.459016	-0.156
4.098361	-0.142
5.737705	-0.12
7.377049	-0.108
9.016393	-0.103
10.65574	-0.081
12.29508	-0.079
13.93443	-0.072
15.57377	-0.056
17.21311	-0.049
18.85246	-0.042
20.4918	-0.034
22.13115	-0.033
23.77049	-0.03
25.40984	-0.024
27.04918	-0.015
28.68852	-0.012
30.32787	-0.01
31.96721	-0.006
33.60656	-0.002
35.2459	-0.001
36.88525	0
38.52459	0
40.16393	0
41.80328	0
43.44262	0
45.08197	0
46.72131	0
48.36066	0.001
50	0.007
51.63934	0.01
53.27869	0.01
54.91803	0.018
56.55738	0.023
58.19672	0.033
59.83607	0.037
61.47541	0.038
63.11475	0.045
64.7541	0.048
66.39344	0.054
68.03279	0.077
69.67213	0.077
71.31148	0.08
72.95082	0.098
74.59016	0.103
76.22951	0.111
77.86885	0.114
79.5082	0.116
81.14754	0.146
82.78689	0.203
84.42623	0.22
86.06557	0.25
87.70492	0.297
89.34426	0.299
90.98361	0.339
92.62295	0.44
94.2623	0.467
95.90164	0.547
97.54098	0.599
99.18033	0.737





Appendix H Regressions for table 5.11

Other Public
Change Index vs Cost Factor

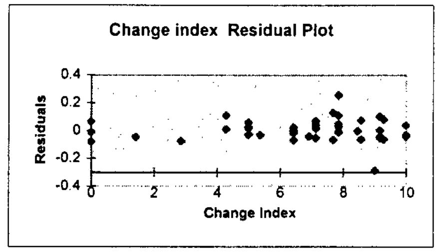
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.057948
R Square	**0.003358**
Adjusted R Square	-0.01982
Standard Error	0.080619
Observations	45

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.000942	0.000942	**0.144878**	**0.705353**
Residual	43	0.279475	0.006499		
Total	44	0.280417			

	Coefficients	Standard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	**0.081564**	0.032834	2.484122	0.016961	0.015348	0.14778	0.015348	0.14778
chgindex	**-0.00171**	0.004492	-0.380628	0.705353	-0.010768	0.007348	-0.010768	0.007348

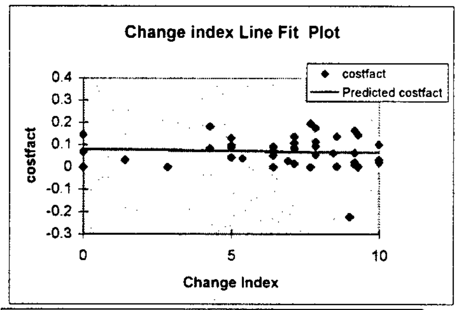


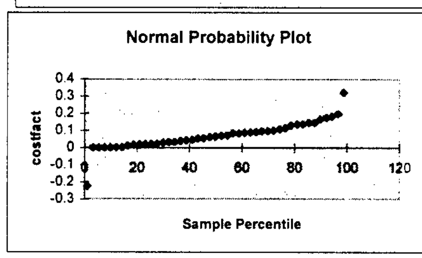
RESIDUAL OUTPUT

Observation	dicted cost.	Residuals	ıdard Residuals
1	0.066177	-0.290177	-3.640977
2	0.081564	-0.081564	-1.023414
3	0.076674	-0.076674	-0.962063
4	0.070571	-0.070571	-0.885482
5	0.068417	-0.068417	-0.858454
6	0.065681	-0.064681	-0.811585
7	0.066912	-0.064912	-0.814482
8	0.065887	-0.053887	-0.676137
9	0.069357	-0.054357	-0.682041
10	0.064468	-0.045468	-0.570501
11	0.064468	-0.044468	-0.557953
12	0.065887	-0.044887	-0.56321
13	0.064468	-0.041468	-0.520311
14	0.069733	-0.041733	-0.523643
15	0.079119	-0.048119	-0.603768
16	0.064468	-0.032468	-0.407384
17	0.072366	-0.034366	-0.431204
18	0.073016	-0.031016	-0.389166
19	0.073016	-0.029016	-0.364071
20	0.070571	-0.018571	-0.233016
21	0.068126	-0.013126	-0.164699
22	0.0671	-0.0051	-0.063996
23	0.065887	-0.001887	-0.023671
24	0.081564	-0.013564	-0.170188
25	0.070571	-0.000571	-0.007162
26	0.074229	0.008771	0.110049
27	0.069357	0.013643	0.171184
28	0.069357	0.017643	0.221374
29	0.073016	0.015984	0.200564
30	0.070571	0.019429	0.243786
31	0.068126	0.025874	0.324651
32	0.073016	0.023984	0.300943
33	0.064468	0.035532	0.445841
34	0.069357	0.038643	0.48487
35	0.068126	0.044874	0.563052
36	0.073016	0.056984	0.715008
37	0.069357	0.066643	0.836198
38	0.066912	0.070088	0.879421
39	0.081564	0.062436	0.783416
40	0.065681	0.078319	0.982698
41	0.065887	0.099113	1.24362
42	0.068126	0.106874	1.340993
43	0.074229	0.106771	1.339697
44	0.068417	0.127583	1.600842
45	0.068126	0.251874	3.16037

PROBABILITY OUTPUT

Percentile	costfact
1.111111	-0.224
3.333333	0
5.555556	0
7.777778	0
10	0
12.22222	0.001
14.44444	0.002
16.66667	0.012
18.88889	0.015
21.11111	0.019
23.33333	0.02
25.55556	0.021
27.77778	0.023
30	0.028
32.22222	0.031
34.44444	0.032
36.66667	0.038
38.88889	0.042
41.11111	0.044
43.33333	0.052
45.55556	0.055
47.77778	0.062
50	0.064
52.22222	0.068
54.44444	0.07
56.66667	0.083
58 88889	0.083
61.11111	0.087
63.33333	0.089
65.55556	0.09
67.77778	0.094
70	0.097
72.22222	0.1
74.44444	0.108
76.66667	0.113
78.88889	0.13
81.11111	0.136
83.33333	0.137
85 55556	0.144
87.77778	0.144
90	0.165
92.22222	0.175
94.44444	0.181
96.66667	0.196
98.88889	0.32





Appendix H Regressions for table 5.11

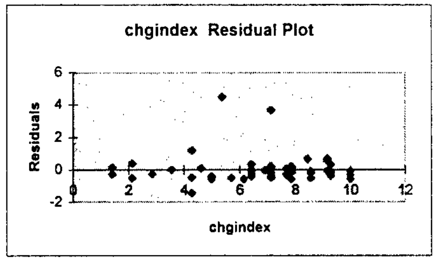
Other Public
Change Index vs Schedule growth

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.244109
R Square	0.059589
Adjusted R Square	0.042491
Standard Error	0.885682
Observations	57

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.733813	2.733813	3.485083	0.067258
Residual	55	43.14379	0.784433		
Total	56	45.8776			



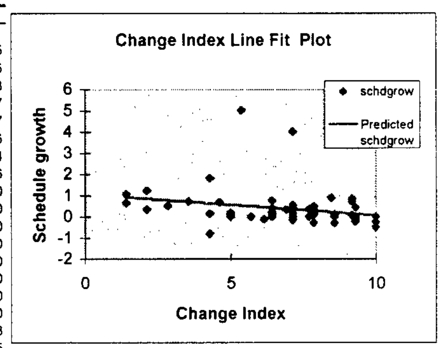
	Coefficients	*Standard Erro.*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.071063	0.381135	2.810192	0.006845	0.307251	1.834875	0.307251	1.834875
chgindex	-0.099447	0.053271	-1.866838	0.067258	-0.206204	0.007309	-0.206204	0.007309

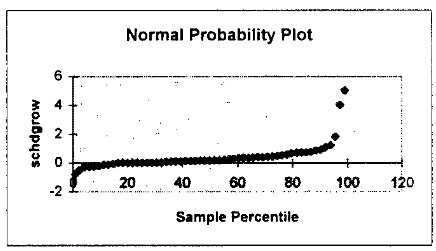
RESIDUAL OUTPUT

Observation	*Predicted sch*	*Residuals*	*Standard Residuals*
1	0.644434	-1.435434	-1.635377
2	0.076589	-0.571589	-0.651206
3	0.218799	-0.524799	-0.597899
4	0.289406	-0.577406	-0.657834
5	0.076589	-0.333589	-0.380055
6	0.147196	-0.374196	-0.426319
7	0.361008	-0.507008	-0.57763
8	0.459461	-0.583461	-0.664733
9	0.147196	-0.233196	-0.265679
10	0.573826	-0.573826	-0.653755
11	0.503218	-0.503218	-0.573312
12	0.431616	-0.431616	-0.491736
13	0.361008	-0.361008	-0.411294
14	0.306312	-0.306312	-0.348979
15	0.147196	-0.147196	-0.1677
16	0.076589	-0.076589	-0.087257
17	0.076589	-0.076589	-0.087257
18	0.218799	-0.210799	-0.240161
19	0.218799	-0.203799	-0.232186
20	0.15913	-0.07913	-0.090152
21	0.431616	-0.339616	-0.386922
22	0.431616	-0.339616	-0.386922
23	0.289406	-0.197406	-0.224903
24	0.218799	-0.110799	-0.126232
25	0.573826	-0.456826	-0.520458
26	0.573826	-0.437826	-0.498811
27	0.289406	-0.138406	-0.157685
28	0.644434	-0.492434	-0.561025
29	0.361008	-0.197008	-0.22445
30	0.573826	-0.395826	-0.450961
31	0.431616	-0.244616	-0.278689
32	0.431616	-0.223616	-0.254764
33	0.289406	-0.049406	-0.056288
34	0.289406	0.005594	0.006373
35	0.289406	0.035594	0.040552
36	0.382887	-0.047887	-0.054557
37	0.306312	0.032688	0.037241
38	0.858246	-0.515246	-0.587015
39	0.361008	0.017992	0.020498
40	0.361008	0.024992	0.028473
41	0.431616	-0.028616	-0.032602
42	0.147196	0.285804	0.325614
43	0.289406	0.186594	0.212585
44	0.786643	-0.273643	-0.31176
45	0.361008	0.185992	0.211899
46	0.928853	-0.280853	-0.319974
47	0.611616	0.081384	0.09272
48	0.15913	0.55887	0.636716
49	0.716036	0.002964	0.003377
50	0.431616	0.316384	0.360454
51	0.15913	0.67987	0.77457
52	0.229738	0.651262	0.741978
53	0.928853	0.134147	0.152832
54	0.858246	0.368754	0.420119
55	0.644434	1.172566	1.335895
56	0.361008	3.655992	4.16524
57	0.536036	4.482964	5.107403

PROBABILITY OUTPUT

Percentile	*schdgrow*
0.877193	-0.791
2.631579	-0.495
4.385965	-0.306
6.140351	-0.288
7.894737	-0.257
9.649123	-0.227
11.40351	-0.146
13.15789	-0.124
14.91228	-0.086
16.66667	0
18.42105	0
20 17544	0
21.92982	0
23.68421	0
25.4386	0
27.19298	0
28.94737	0
30.70175	0.008
32 45614	0.015
34.21053	0.08
35.96491	0.092
37.7193	0.092
39.47368	0.092
41.22807	0.108
42.98246	0.117
44.73684	0.136
46 49123	0.151
48.24561	0.152
50	0.164
51.75439	0.178
53.50877	0.187
55.26316	0.208
57.01754	0.24
58.77193	0.295
60.52632	0.325
62.2807	0.335
64.03509	0.339
65.78947	0.343
67.54386	0.379
69.29825	0.386
71.05263	0.403
72.80702	0.433
74.5614	0.476
76.31579	0.513
78.07018	0.547
79.82456	0.648
81.57895	0.693
83.33333	0.718
85.08772	0.719
86.84211	0.748
88.59649	0.839
90.35088	0.881
92.10526	1.063
93.85965	1.227
95.61404	1.817
97.36842	4.017
99.12281	5.019

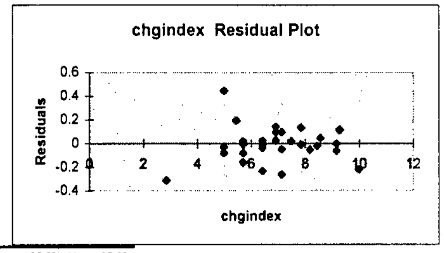




Appendix H for Table 5.11

SUMMARY OUTPUT

Regression Statistics		Navy
Multiple R	0.157569	**Change Index vs. Cost Growth**
R Square	0.024828	
Adjusted R Square	-0.004723	
Standard Error	0.1627	
Observations	35	



ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.022241	0.022241	0.840185	0.3659944
Residual	33	0.873552	0.026471		
Total	34	0.895793			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.121413	0.122054	0.99475	0.327096	-0.1269072	0.369733	-0.126907	0.369733
chgindex	-0.015983	0.017437	-0.916616	0.365994	-0.0514591	0.019493	-0.051459	0.019493

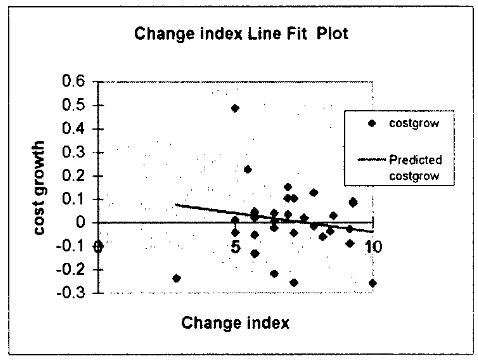
=.12-.0159 chngidx

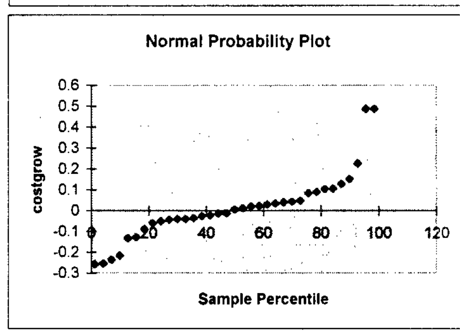
RESIDUAL OUTPUT

Observation	*Predicted c*	*Residuals*	*Standard Residuals*
1	0.007293	-0.262293	-1.636374
2	0.030149	0.011851	0.073933
3	0.030149	-0.009149	-0.05708
4	0.030149	0.016851	0.105126
5	0.030149	-0.082149	-0.512506
6	0.018642	-0.234642	-1.463861
7	0.041497	0.445503	2.779363
8	0.041497	-0.082497	-0.514677
9	0.075701	-0.312701	-1.950853
10	-0.025152	-0.002848	-0.017767
11	-0.025152	-0.063848	-0.398328
12	-0.013804	-0.023196	-0.144712
13	0.007293	0.095707	0.597085
14	0.01081	0.14119	0.880845
15	0.018642	-0.040642	-0.253551
16	-0.004214	-0.009786	-0.06105
17	-0.004214	-0.010786	-0.067289
18	0.01081	0.09319	0.581387
19	0.041497	-0.082497	-0.514677
20	0.041497	0.445503	2.779363
21	-0.015585	0.044556	0.277971
22	0.007248	-0.051483	-0.32119
23	-0.027002	0.110335	0.688348
24	0.030081	-0.159605	-0.995727
25	-0.004169	0.13162	0.821137
26	-0.027002	0.116848	0.728983
27	0.030081	-0.162915	-1.016383
28	0.010761	0.023068	0.143914
29	0.00154	0.017964	0.112072
30	0.041497	-0.030756	-0.191879
31	0.018664	0.021335	0.133105
32	-0.038418	-0.219569	-1.36983
33	-0.009358	-0.051675	-0.322385
34	0.034232	0.191574	1.195176
35	0.018664	-0.014056	-0.087692

PROBABILITY OUTPUT

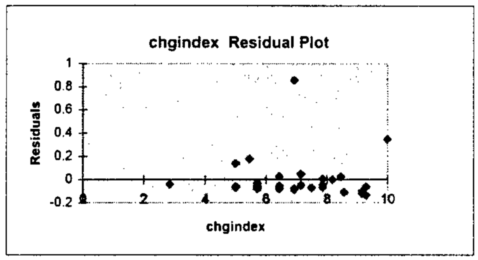
Percentile	*costgrow*
1.4285714	-0.257988
4.2857143	-0.255
7.1428571	-0.237
10	-0.216
12.857143	-0.132835
15.714286	-0.129524
18.571429	-0.089
21.428571	-0.061033
24.285714	-0.052
27.142857	-0.044236
30	-0.041
32.857143	-0.041
35.714286	-0.037
38.571429	-0.028
41.428571	-0.022
44.285714	-0.015
47.142857	-0.014
50	0.004608
52.857143	0.010741
55.714286	0.019504
58.571429	0.021
61.428571	0.028971
64.285714	0.033829
67.142857	0.04
70	0.042
72.857143	0.047
75.714286	0.083333
78.571429	0.089847
81.428571	0.103
84.285714	0.104
87.142857	0.127451
90	0.152
92.857143	0.225806
95.714286	0.487
98.571429	0.487





Appendix H for Table 5.11

NAVFAC
Change Index vs. Cost Factor
Un adjusted



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.121326
R Square	0.01472
Adjusted R Square	-0.015137
Standard Error	0.179357
Observations	35

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.01586	0.01586	0.493017	0.487508
Residual	33	1.061576	0.032169		
Total	34	1.077436			

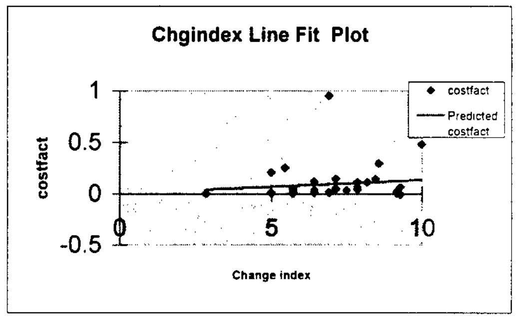
	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00283	0.134549	0.02103	0.983348	-0.270913	0.276573	-0.270913	0.276573
chgindex	0.013497	0.019222	0.702152	0.487508	-0.025611	0.052605	-0.025611	0.052605

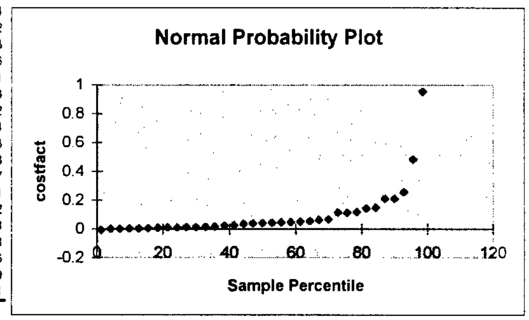
RESIDUAL OUTPUT

Observation	*Predicted cos*	*Residuals*	*Standard Residuals*
1	0.099198	-0.046198	-0.261448
2	0.079897	-0.037897	-0.214472
3	0.079897	-0.036897	-0.208813
4	0.079897	-0.028897	-0.163538
5	0.079897	-0.068897	-0.389911
6	0.089615	0.027385	0.15498
7	0.070314	0.137686	0.779206
8	0.070314	-0.069314	-0.392272
9	0.041431	-0.041431	-0.234471
10	0.126597	-0.102597	-0.580627
11	0.126597	-0.121597	-0.688154
12	0.117014	0.023986	0.135745
13	0.099198	-0.053198	-0.301063
14	0.096229	0.854771	4.837422
15	0.089615	-0.053615	-0.303424
16	0.108916	-0.068916	-0.390015
17	0.108916	-0.046916	-0.265511
18	0.096229	-0.080229	-0.454039
19	0.070314	-0.069314	-0.392272
20	0.070314	0.137686	0.779206
21	0.118518	-0.110903	-0.627637
22	0.099236	0.046976	0.265852
23	0.128158	-0.062224	-0.352147
24	0.079955	-0.079955	-0.452491
25	0.108877	0.003471	0.019642
26	0.128158	-0.136872	-0.7746
27	0.079955	-0.058444	-0.330755
28	0.09627	-0.08902	-0.503793
29	0.104057	-0.071013	-0.401887
30	0.070314	-0.059687	-0.337789
31	0.089596	-0.081114	-0.459052
32	0.137799	0.343509	1.944028
33	0.113259	-0.002426	-0.013729
34	0.076449	0.177937	1.006999
35	0.089596	-0.075834	-0.42917

PROBABILITY OUTPUT

Percentile	*costfact*
1.428571	-0.008713
4.285714	0
7.142857	1E-20
10	0.001
12.85714	0.001
15.71429	0.005
18.57143	0.00725
21.42857	0.007614
24.28571	0.008481
27.14286	0.010627
30	0.011
32.85714	0.013761
35.71429	0.016
38.57143	0.021511
41.42857	0.024
44.28571	0.033043
47.14286	0.036
50	0.04
52.85714	0.042
55.71429	0.043
58.57143	0.046
61.42857	0.051
64.28571	0.053
67.14286	0.062
70	0.065934
72.85714	0.110833
75.71429	0.112348
78.57143	0.117
81.42857	0.141
84.28571	0.146212
87.14286	0.208
90	0.208
92.85714	0.254386
95.71429	0.481309
98.57143	0.951





Appendix H for Table 5.11

NAVFAC
Change Index vs Cost fact
*** Grass roots only**

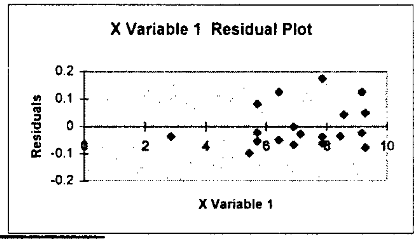
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.128792
R Square	0.016587
Adjusted R Square	-0.04126
Standard Error	0.079656
Observations	19

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.001819	0.001819	0.286742	0.599252
Residual	17	0.107867	0.006345		
Total	18	0.109686			

	Coefficient	*'andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Ipper 95.0%*
Intercept	**0.116916**	0.082924	1.409921	0.176596	-0.05804	0.291871	-0.05804	0.291871
X Variable 1	**-0.00673**	0.012572	-0.53548	0.599252	-0.03326	0.019792	-0.03326	0.019792

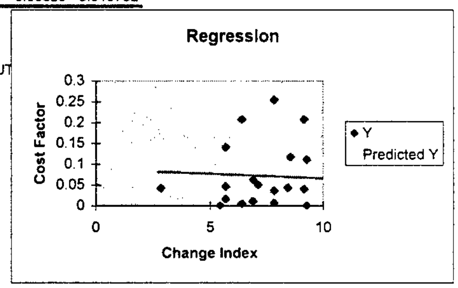


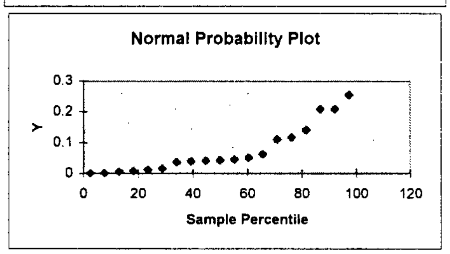
RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*dard Residuals*
1	0.078477	-0.03648	-0.4712
2	0.078477	-0.03548	-0.45829
3	0.078477	-0.02748	-0.35494
4	0.078477	-0.06748	-0.87166
5	0.07363	0.04337	0.560253
6	0.083256	0.124744	1.611424
7	0.097663	-0.09766	-1.2616
8	0.055184	-0.05018	-0.64827
9	0.059964	0.081036	1.046817
10	0.06885	-0.02285	-0.29517
11	0.07363	-0.03763	-0.4861
12	0.064003	-0.024	-0.31007
13	0.064003	-0.002	-0.02587
14	0.070331	-0.05433	-0.70184
15	0.083256	0.124744	1.611424
16	0.078448	-0.07845	-1.01338
17	0.07031	-0.06306	-0.81461
18	0.061837	0.048997	0.632936
19	0.080197	0.174189	2.250162

PROBABILITY OUTPUT

Percentile	*Y*
2.631579	0
7.894737	1E-20
13.15789	0.005
18.42105	0.00725
23.68421	0.011
28.94737	0.016
34.21053	0.036
39.47368	0.04
44.73684	0.042
50	0.043
55.26316	0.046
60.52632	0.051
65.78947	0.062
71.05263	0.110833
76.31579	0.117
81.57895	0.141
86.84211	0.208
92.10526	0.208
97.36842	0.254386





Appendix H for Table 5.11

NAVY
Change Index vs. Schedule growth

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.3296784
R Square	0.1086878
Adjusted R Sq	0.0779529
Standard Erroi	0.9363955
Observations	31

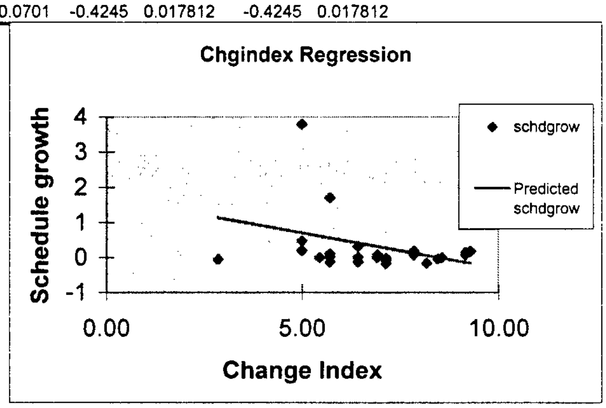
ANOVA

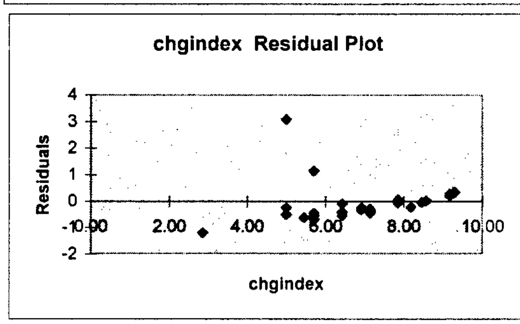
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.10075669	3.1007567	3.5363	0.07012
Residual	29	25.4282576	0.8768365		
Total	30	28.5290143			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.7293124	0.74665872	2.316068	0.0278	0.20222	3.256402	0.202223	3.256402
chgindex	-0.2033452	0.10813331	-1.880505	0.0701	-0.4245	0.017812	-0.4245	0.017812

RESIDUAL OUTPUT

Observation	*Predicted schdgrow*	*Residuals*	*Standard Residuals*
1	0.2768464	-0.44670937	-0.485207
2	0.0655786	-0.2333638	-0.253475
3	0.5673396	-0.69646045	-0.756482
4	0.422093	-0.54656554	-0.593669
5	0.2774273	-0.35942734	-0.390403
6	1.147745	-1.200745	-1.304227
7	0.0090116	-0.05001161	-0.054322
8	0.2774273	-0.29642734	-0.321974
9	0.3221633	-0.3221633	-0.349928
10	-0.0136469	0.01364686	0.014823
11	0.422093	-0.42209296	-0.458469
12	0.6201565	-0.62015651	-0.673602
13	0.4218025	-0.41480247	-0.450551
14	0.568211	-0.55521105	-0.60306
15	0.568211	-0.53821105	-0.584595
16	0.1315997	-0.06337363	-0.068835
17	-0.1353635	0.21036351	0.2284929
18	0.3215376	-0.24161959	-0.262443
19	0.568211	-0.45921105	-0.498786
20	-0.1353635	0.27636351	0.3001809
21	-0.1588935	0.31815272	0.3455715
22	0.1310188	0.03598124	0.0390821
23	-0.1588935	0.33792572	0.3670486
24	0.1310188	0.06098124	0.0662367
25	0.7125862	-0.50850454	-0.552328
26	0.4218025	-0.10380247	-0.112748
27	0.7125862	-0.23958617	-0.260234
28	0.7125862	-0.23958617	-0.260234
29	0.568211	1.14178895	1.2401898
30	0.7125862	3.08141383	3.3469741
31	0.7125862	3.08141383	3.3469741





Appendix I Regressions for Table 5.12

Appendix I Regressions for table 5.12

NAVFAC
Change Index vs Cost growth
all Grass-roots

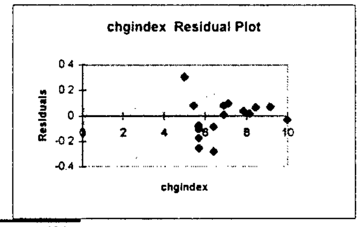
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.608265577
R Square	**0.369987012**
Adjusted R Square	0.332927424
Standard Error	0.158302453
Observations	19

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.250185	0.250185	**9.983571**	**0.005723**
Residual	17	0.426014	0.02506		
Total	18	0.676199			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	**0.591482224**	0.179954	3.286846	0.004352	0.211811	0.971153	0.211811	0.971153
chgindex	**-0.08178054**	0.025883	-3.159679	0.005723	-0.136388	-0.027173	-0.136388	-0.027173

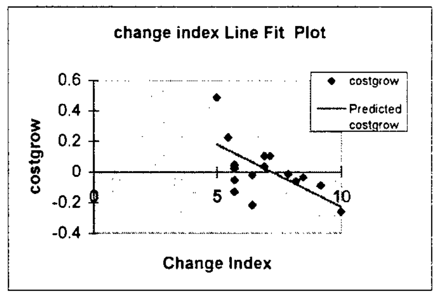


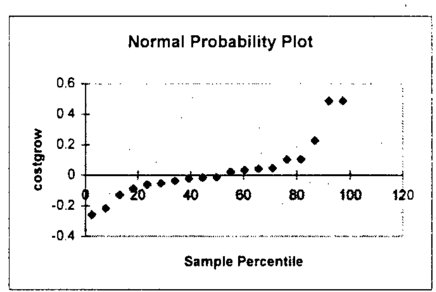
RESIDUAL OUTPUT

Observation	*Predicted costgr*	*Residuals*	*Standard Residuals*
1	0.182579505	0.30442	1.978782
2	0.182579505	0.30442	1.978782
3	0.14540653	0.0804	0.522612
4	0.124515319	-0.176515	-1.147378
5	0.124515319	-0.103515	-0.672866
6	0.124515319	-0.082515	-0.536363
7	0.124515319	-0.077515	-0.503862
8	0.124164831	-0.253689	-1.649017
9	0.065633327	-0.281633	-1.830662
10	0.065633327	-0.087633	-0.569631
11	0.025560861	0.078439	0.509867
12	0.025309228	0.008519	0.055377
13	0.007569141	0.095431	0.620316
14	-0.05131285	0.036313	0.236039
15	-0.05131285	0.037313	0.24254
16	-0.07763132	0.016598	0.107893
17	-0.10038118	0.063381	0.411988
18	-0.15844536	0.069445	0.451406
19	-0.22632321	-0.031664	-0.205823

PROBABILITY OUTPUT

Percentile	*costgrow*
2.631579	-0.257988
7.894737	-0.216
13.15789	-0.129524
18.42105	-0.089
23.68421	-0.061033
28.94737	-0.052
34.21053	-0.037
39.47368	-0.022
44.73684	-0.015
50	-0.014
55.26316	0.021
60.52632	0.033829
65.78947	0.042
71.05263	0.047
76.31579	0.103
81.57895	0.104
86.84211	0.225806
92.10526	0.487
97.36842	0.487





Appendix I Regressions for table 5.12

NAVFAC
Change Index vs Cost growth
Grass-roots <$15M

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.580280777
R Square	**0.33672578**
Adjusted R Square	0.281452929
Standard Error	0.173340008
Observations	***14***

ANOVA

	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	0.183047	0.183047	6.092	**0.030**
Residual	12	0.360561	0.030047		
Total	13	0.543608			

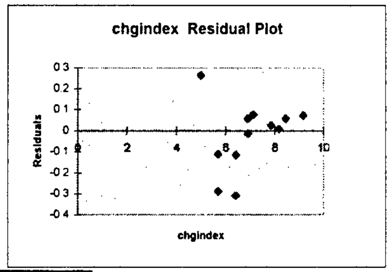
	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	**0.684766363**	0.261935	2.614262	0.0226	0.11406	1.255473	0.114059	1.255473
chgindex	**-0.092030296**	0.037286	-2.468211	0.0296	-0.1733	-0.010791	-0.17327	-0.010791

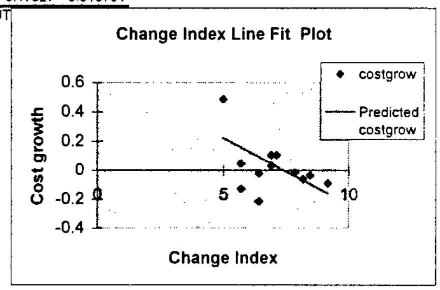
RESIDUAL OUTPUT

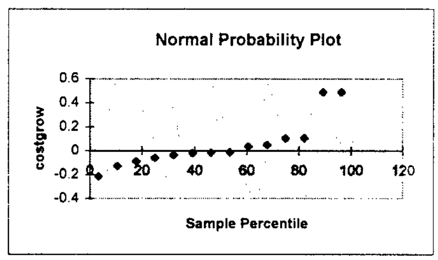
Observation	*Predicted costgrow*	*Residuals*	*Standard Residuals*
1	0.224614885	0.262385	1.575511
2	0.224614885	0.262385	1.575511
3	0.159273375	-0.112273	-0.674154
4	0.15887896	-0.288403	-1.731736
5	0.093011562	-0.309012	-1.855483
6	0.093011562	-0.115012	-0.690596
7	0.047916717	0.056083	0.336756
8	0.047633547	-0.013805	-0.082893
9	0.027670052	0.07533	0.452324
10	-0.03859176	0.023592	0.141658
11	-0.03859176	0.024592	0.147663
12	-0.068208783	0.007176	0.043088
13	-0.093809938	0.05681	0.34112
14	-0.159151448	0.070151	0.42123

PROBABILITY OUTPUT

Percentile	*costgrow*
3.57143	-0.216
10.7143	-0.129524
17.8571	-0.089
25	-0.061033
32.1429	-0.037
39.2857	-0.022
46.4286	-0.015
53.5714	-0.014
60.7143	0.033829
67.8571	0.047
75	0.103
82.1429	0.104
89.2857	0.487
96.4286	0.487





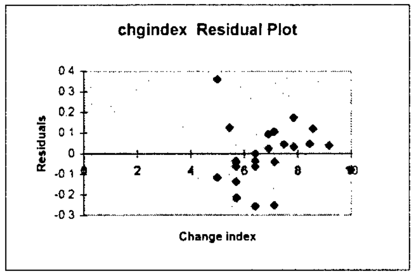


Appendix I Regressions for table 5.12

NAVFAC
Change Index vs Cost growth
all Buildings

SUMMARY OUTPUT

Regression Statistics	
Multiple R	*0.460767*
R Square	0.212307
Adjusted R Square	0.180799
Standard Error	0.157681
Observations	27



ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.167534	0.167534	6.738235	0.015573
Residual	25	0.62158	0.024863		
Total	26	0.789114			

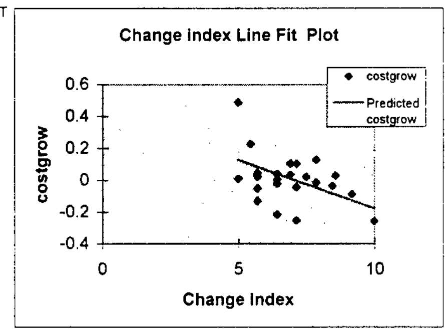
	Coefficients	*Standard E*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Ipper 95.0%*
Intercept	0.43195	0.161891	2.668154	0.013194	0.098529	0.76537	0.098529	0.76537
chgindex	-0.06091	0.023464	-2.59581	0.015573	-0.10923	-0.01258	-0.10923	-0.01258

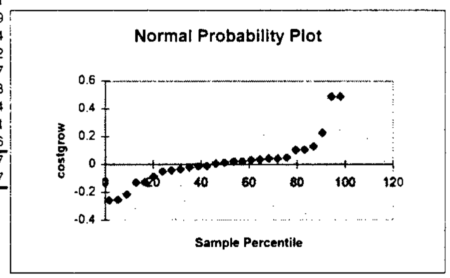
RESIDUAL OUTPUT

Observation	Predicted (	Residuals	Standard Residuals
1	0.127408	-0.11667	-0.75454
2	0.127408	0.359592	2.325674
3	0.127408	0.359592	2 325674
4	0.099722	0.126085	0.815455
5	0.084163	-0.13616	-0.88064
6	0.084163	-0.06316	-0.40851
7	0.084163	-0.04216	-0.27269
8	0.084163	-0.03716	-0.24035
9	0.083902	-0.21674	-1.40175
10	0.083902	-0.21343	-1.38033
11	0.040396	-0.03579	-0.23145
12	0.040396	-0.0004	-0.00256
13	0.040309	-0.25631	-1.65768
14	0.040309	-0.06231	-0.40298
15	0.010463	0.093537	0.604951
16	0.010276	0.023553	0.152327
17	-0.00294	-0.25206	-1.63023
18	-0.00294	0.105936	0.685147
19	-0.00311	-0 04113	-0.26598
20	-0.02486	0.044367	0.286945
21	-0.04662	0.174067	1.125786
22	-0.04679	0.031791	0.205606
23	-0.04679	0.032791	0.212074
24	-0.08334	0.046336	0.299677
25	-0.09012	0.119093	0.770238
26	-0.12658	0.037581	0.243053
27	-0.17713	-0.08085	-0.52292

PROBABILITY OUTPUT

Percentile	costgrow
1.851852	-0.25799
5.555556	-0.255
9.259259	-0.216
12.96296	-0.13283
16.66667	-0.12952
20.37037	-0.089
24.07407	-0.052
27.77778	-0.04424
31.48148	-0.037
35.18519	-0.022
38.88889	-0.015
42.59259	-0.014
46.2963	0.004608
50	0.010741
53.7037	0.019504
57.40741	0.021
61.11111	0.028971
64.81481	0.033829
68 51852	0.04
72.22222	0.042
75.92593	0.047
79.62963	0.103
83.33333	0.104
87.03704	0.127451
90 74074	0.225806
94.44444	0.487
98.14815	0.487





Appendix J Practice Use by Dataset

Appendix J-1

NAVFAC Practice use

New Navy

Project Change Management Practices	Yes	No	Total	UnK	% yes	% no	% Unk
1 Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?	12	3	15	0	133%	33%	0%
2 Was a baseline project scope established early in the project and frozen with changes managed against this base?	14	0	14	1	156%	0%	7%
3 Were design "freezes" established and communicated once designs were complete?	5	6	11	4	56%	67%	27%
4 Were areas susceptible to change identified and evaluated for risk during review of the project design basis?	5	6	11	4	56%	67%	27%
5 Were changes on this project evaluated against the business drivers and success criteria for the project?	4	8	12	3	44%	89%	20%
6 Were all changes required to go through a formal change justification procedure?	8	6	14	1	89%	67%	7%
7 Was authorization for change mandatory before implementation?	14	1	15	0	156%	11%	0%
8 Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?	14	1	15	0	156%	11%	0%
9 Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?	15	0	15	0	167%	0%	0%
10 Did the project contract address criteria for classifying change personnel authorized to request and approve change, and the basis for adjusting the contract?	14	1	15	0	156%	11%	0%
11 Was a tolerance level for changes established and communicated to all project participants?	12	3	15	0	133%	33%	0%
12 Were all changes processed through one owner representative?	13	2	15	0	144%	22%	0%
13 At project closeout, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?	8	7	15	0	89%	78%	0%
14 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?	2	12	14	1	22%	133%	7%
	140	56	196	14			
	67%	27%	210	7%			

Combined- All Navy

	Yes	No	UnK	Total	% yes	% no	% Unk
9	35	0	0	35	100%	0%	0%
7	34	1	0	35	97%	3%	0%
10	34	1	0	35	97%	3%	0%
8	32	3	0	35	91%	9%	0%
2	30	4	1	35	86%	11%	3%
12	30	5	0	35	86%	14%	0%
1	26	9	0	35	74%	26%	0%
3	20	10	5	35	57%	29%	14%
6	19	15	1	35	54%	43%	3%
11	17	16	2	35	49%	46%	6%
4	14	16	5	35	40%	46%	14%
13	10	25	0	35	29%	71%	0%
5	7	22	5	34	20%	63%	14%
14	7	27	1	35	20%	77%	3%
	315	154	20	469			
	64%	31%	4%	490			

Appendix J-2

Other Public Projects Practice use

Elements in Order

Project Change Management Practices	Yes	No	UnK	Total	% yes	% no	% Unk
1. Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?	50	17	0	67	75%	25%	0%
2. Was a baseline project scope established early in the project and frozen with changes managed against this base?	46	20	0	66	69%	30%	0%
3. Were design "freezes" established and communicated once designs were complete?	36	25	5	66	54%	37%	7%
4. Were areas susceptible to change identified and evaluated for risk during review of the project design basis?	31	34	2	67	46%	51%	3%
5. Were changes on this project evaluated against the business drivers and success criteria for the project?	27	36	4	67	40%	54%	6%
6. Were all changes required to go through a formal change justification procedure?	44	23	0	67	66%	34%	0%
7. Was authorization for change mandatory before implementation?	56	11	0	67	84%	16%	0%
8. Was a system in place to ensure timely communication of change information to the proper disciplines	53	13	1	67	79%	19%	1%
9. Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?	60	6	1	67	90%	9%	1%
10. Did the project contract address criteria for classifying change.	54	11	2	67	81%	16%	3%
11. Was a tolerance level for changes established and communicated	37	26	3	66	55%	39%	4%
12. Were all changes processed through one owner representative?	56	10	1	67	84%	15%	1%
13. At project closeout, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons	31	32	4	67	46%	48%	6%
14. 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?	20	43	3	66	30%	64%	4%
	601	307	26	908			
	64%	33%	3%	938			

Elements ranked by use

Quest	Yes	No	UnK	Total	% yes	% no	% Unk
9	60	6	1	67	90%	9%	1%
12	56	10	1	67	84%	15%	1%
7	56	11	0	67	84%	16%	0%
10	54	11	2	67	81%	16%	3%
8	53	13	1	67	79%	19%	1%
1	50	17	0	67	75%	25%	0%
2	46	20	0	66	69%	30%	0%
6	44	23	0	67	66%	34%	0%
11	37	26	3	66	55%	39%	4%
3	36	25	5	66	54%	37%	7%
13	31	32	4	67	46%	48%	6%
4	31	34	2	67	46%	51%	3%
5	27	36	4	67	40%	54%	6%
14	20	43	3	66	30%	64%	4%
	601	307	26	908			
	64%	33%	3%	938			

Appendix J-3

Other CII Projects: Practice use

Elemnets in Order

Project Change Management Practices	Yes	No	UnK	Total	% yes	% no	% Unk
1. Was a formal documented change management process, familiar	249	42	1	292	85%	14%	0%
2 Was a baseline project scope established early in the project and	261	31	0	292	89%	11%	0%
3. Were design "freezes" established and communicated once	205	83	4	292	70%	28%	1%
4. Were areas susceptible to change identified and evaluated for	176	108	8	292	60%	37%	3%
5. Were changes on this project evaluated against the business drivers	217	67	8	292	74%	23%	3%
6. Were all changes required to go through a formal change justification	215	75	2	292	74%	26%	1%
7. Was authorization for change mandatory before implementation?	260	28	4	292	89%	10%	1%
8. Was a system in place to ensure timely communication of change	273	17	2	292	93%	6%	1%
9. Did project personnel take proactive measures to promptly settle,	266	24	2	292	91%	8%	1%
10 Did the project contract address criteria for classifying change,	236	46	10	292	81%	16%	3%
11. Was a tolerance level for changes established and	179	106	7	292	61%	36%	2%
12. Were all changes processed through one owner representative?	259	29	4	292	89%	10%	1%
13. At project closeout, was an evaluation made of changes and their	166	112	14	292	57%	38%	5%
14. Was the project organized in a Work Breakdown Structure (WBS) format and	164	124	4	292	56%	42%	1%
	3126	892	70	4018			
	76%	22%	2%	4088			

Elements ranked by use

Quest	Yes	No	UnK	Total	% yes	% no	% Unk
8	273	17	2	292	93%	6%	1%
9	266	24	2	292	91%	8%	1%
2	261	31	0	292	89%	11%	0%
7	260	28	4	292	89%	10%	1%
12	259	29	4	292	89%	10%	1%
1	249	42	1	292	85%	14%	0%
10	236	46	10	292	81%	16%	3%
5	217	67	8	292	74%	23%	3%
6	215	75	2	292	74%	26%	1%
3	205	83	4	292	70%	28%	1%
11	179	106	7	292	61%	36%	2%
4	176	108	8	292	60%	37%	3%
13	166	112	14	292	57%	38%	5%
14	164	124	4	292	56%	42%	1%
	3126	892	70	4018			
	76%	22%	2%	4088			

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Vita

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