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ELEMENTS OF SUCCESS FOR U.S. AIR FORCE MILITARY CONSTRUCTION PROJECTS

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ELEMENTS OF SUCCESS FOR U.S. AIR FORCE MILITARY CONSTRUCTION PROJECTS

by

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THESIS

Presented to the Faculty of the Graduate School of
The University of Texas at Austin
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Requirements for
the Degree of

MASTER OF SCIENCE IN ENGINEERING

THE UNIVERSITY OF TEXAS AT AUSTIN

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ABSTRACT

ELEMENTS OF SUCCESS FOR U.S. AIR FORCE MILITARY CONSTRUCTION PROJECTS

by
STEVEN ANDREW DAVIS, MASTER OF SCIENCE IN ENGINEERING
THE UNIVERSITY OF TEXAS AT AUSTIN, 1993
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A wide range of U.S. Air Force construction projects completed in the continental United States were evaluated to (1) measure the effectiveness of factors impacting the construction process, (2) measure the key indicators of project success, and (3) determine the relationship between these input factors and indicators of success. Input factors and measures of success were developed from previous research and applied to the military construction environment. The four key measures proposed to indicate project success included: (1) project quality and performance, (2) cost variability, (3) schedule performance, and (4) safety. The factors assumed to most significantly impact success were: (1) design basis, (2) qualified key leaders, (3) compatible objectives, (4) well defined responsibilities, (5) control systems, and (6) project environment.

An objectives matrix approach was used to combine input factor criteria and create an evaluation index for each project. The same process was used for the output measures criteria. Input and output indexes were plotted against each other and analyzed to determine the degree of correlation.

Relatively high indexes indicated good project management in general. In addition, data indicated a relatively strong linear correlation between input and output indexes. Finally, the logical cause-and-effect relationship suggests that it is possible to predict project success based upon input data. Therefore, the objectives matrix evaluation of input factors would be a good predictor of ultimate project success.

Table of Contents

1. Introduction

1.1 Purpose

This research is designed to determine the key factors which have a critical impact on the success of a constructed project. The goal is to identify factors assumed to impact construction project success, and measure resulting success in a way that (1) generates an input factor index value by evaluating and combining the input factors identified, and (2) generates an output measures index value by determining and combining the output measures identified, so that the two indexes may be plotted against each other for a number of projects to determine whether they have a relationship.

The research hypothesis is that well accomplished input factors should ensure ultimate project success. If input factor measures are related to project success, they could be used to predict project outcome. If the outcome is not predicted as positive, input measures should give project managers an idea of which areas to correct, in order to improve that outcome.

1.2 Scope

Twenty-two U.S. Air Force construction projects have been evaluated to (1) measure the effectiveness of inputs to the construction process, and (2) measure the indicators of project success. The projects represent a wide range of construction types for the U.S. Air Force in the continental United States. The projects are listed in Chapter 3. Major inputs and measures of success were suggested by previous research and validated by a panel of military construction project managers. The proposed measures of project success include: (1) project performance, (2) cost variability, (3) schedule performance, and (4) safety performance. Factors assumed to impact success are: (1) design basis, (2) qualified key leaders, (3) compatible objectives, (4) well defined responsibilities, (5) control systems, and (6) project environment.

Project data were collected by surveying military construction project managers from the U.S. Air Force Center for Environmental Excellence (AFCEE) at Brooks Air Force Base, Texas, and by obtaining compiled project data from the AFCEE

Programming, Design, and Construction (PDC) project database for recently completed projects.

An objectives matrix approach was used to combine criteria and create both an input factors evaluation and an output measures index for each project. An output sensitivity analysis was conducted to determine the emphasis of output criteria weighting on the output measures index for each project. Input factors and output measures indexes were compared and plotted and a regression analysis performed to determine their relationship.

2. Background

2.1 Importance of Construction Metrics

Metrics are measures of how well we do things. Good metrics (1) are meaningful to the customer; (2) tell how well organizational goals and objectives are met; (3) are simple, logical, and repeatable; (4) show a trend; (5) are defined unambiguously; (6) are economical to collect; (7) are timely; and (8) drive the "appropriate action." Initial and ongoing metrics are necessary in improving any process. Initial metrics evaluate past performance and determine how effective efforts have been in achieving objectives. Ongoing metrics measure the results of improvement efforts, point out subpar performance and problem areas, and most importantly, drive the "appropriate action."

A construction measurement system, beginning with a project database identifying project performance and corresponding input efforts, can be a powerful management tool. Construction metrics can be used to compare the progress of ongoing projects against past projects and flag shortfalls and problems to management attention. Compiled "lessons learned" can suggest effective actions in alleviating problems or in optimizing performance by identifying what has worked well and what has not worked well for past projects. Finally, metrics can determine how effective improvement and innovation efforts are in achieving project success by evaluating the "innovative" project against the "standard" project.

2.2 Measures of Success

Elementally, project success means meeting or exceeding project objectives set early in a project. Carrying this one step further, project success is incomplete unless it leads to the success of larger organizational objectives. Therefore, success can best be evaluated by measuring the level of accomplishment of a project's unique objectives, and the objectives of the larger organization relating to that project.

The best indicator of project success, customer satisfaction, is usually not completely available until the facility has been in service, possibly not until after it has served its useful life. However, it is very difficult to compile complete data for these projects, since all of the people familiar with them are usually not available. In addition, long-term results don't provide the immediate feedback necessary to improve the process for upcoming projects. Therefore, the most practical time to get data is probably at or near the end of a project.

A Construction Industry Institute (CII) study identified design outcome parameters focused primarily on end-of-project or post-project results. The most significant parameters were identified as follows: (1) final project schedule, (2) constructability, (3) quality of design, (4) final project cost, (5) plant start-up, (6) plant performance, and (7) safety (CII Publication 8-2, 87). The final project schedule parameter identifies how well the schedule objectives of the project were met. Constructability is the integration of construction knowledge and experience in planning, engineering, procurement, and field operations to achieve project objectives. Quality of design evaluated design documents, including drawings and specifications for meeting the owner's specified requirements, completeness, correctness, clarity and timeliness. Final project cost is how well total facility cost, including design and construction, met budget requirements. Plant start-up is the effort to bring a plant into operation and prepare it for occupancy. It consists of a series of checks to ensure it will operate as designed. Performance relates to meeting operating requirements throughout the life of a facility. These will vary for each project depending on the owner's objectives, but may include flexibility, reliability, capacity, economy of maintenance, and aesthetics. Safety evaluates the accident record of construction and the safety problems of the completed facility.

These seven parameters were considered for applicability to different projects for this research. A discussion of selection of the final parameters is in chapter 4.

2.3 Factors Impacting Success

The Project Organization Task Force of the Construction Industry Institute (CII) identified the following elements that determine project success: (1) key leaders, (2) compatible objectives, (3) design basis, (4) project strategy, (5) roles and responsibilities, (6) information systems, (7) qualified people, and (8) working relationships (Carroll 89). These factors vary in importance depending on the client and the type of facility being constructed.

Key leaders: the project executive, the owner's project manager, and the general superintendent, are mainly concerned with work flow rather than specific work packages. The project executive determines the owner's objectives and establishes direction for the project. The owner's project manager takes the direction of the project executive in managing design, procurement, and construction activities. The general superintendent plans and coordinates construction field activities.

The owner determines and prioritizes project objectives and communicates them through contracts and planning documents. Differences and conflicts should be discussed and resolved to eliminate work barriers.

The design basis is the compiled input for the design process. Design basis includes specific processes and facility requirements, project scope, site investigations, design standards, necessary reviews and analyses, etc.

The project strategy is the overall plan to accomplish a project, including a contracting strategy, a facilities plan, an external map, and a project schedule. A contracting strategy includes an explanation of organization functions, as well as an acquisition plan identifying potential sources of materials and services, and the means of obtaining them. A facilities plan defines the environment in which work will be performed, including work locations, temporary facilities, logistics, and communications. An external map identifies the entities which influence the project, even though they may not have a direct contractual relationship. The project schedule is the timing of engineering, procurement, and construction tasks. The schedule must include input from all significant parties: the owner, designer, constructor and major vendors.

Contractual agreements establish the roles and responsibilities of parties. They should be written to promote cooperation and avoid adversarial relationships. Authority should go with responsibility and risks should be assigned to those who can best control them. Contracts should encourage the participation of qualified organizations and reflect the agreement between them. Special provisions should be used to state expectations, including participation in the management process.

Information systems gather, compile, and distribute data for scheduling, materials, equipment, and facilities management.

Each function must be staffed with qualified personnel. The project manager for each organization and key leaders are the most important. Qualified people can work around shortfalls in the formal organization.

Effective communication depends upon mutual cooperation. Individuals involved in project processes should be part of establishing flow charts and project-wide communication systems. Participants will better understand the needs of other organizations and will have a personal commitment to make their system work.

2.3 The U.S. Air Force Military Construction (MILCON) Process

The military construction process is much like that of any corporation. Requirements are identified, a project is planned, authorized, and constructed to meet those requirements, and the resulting facility is operated. The overall process is shown in Figure 2.1.

The "typical" MILCON project starts when a using activity identifies a requirement to the Base Civil Engineer (BCE). The BCE, through the civil engineering operations and contract programming branch, determines whether the work will require a MILCON project. MILCON projects are usually reserved for more complex construction activities costing more than $200,000. The project must be validated and approved by a base level facilities board representing the major base using agencies, civil engineering, and the wing commander. If it passes this test, it is submitted to the Major Command (MAJCOM), which then must approve and submit it to the Headquarters US Air Force (HQ USAF) facilities panel for design approval. Once validated, design is authorized and a design instruction is issued by AF/LEE, the Air Force Directorate of Engineering. The project is placed in the Program Objective Memorandum (POM) for review by the Office of the Secretary of Defense (OSD) and the Joint Chiefs of Staff (JCS). Design starts while the project, along with other Department of Defense projects in the POM, is being reviewed.

Ideally, design reaches 35% at the start of the budget process. Approved projects are submitted in the Air Force Budget Estimate Submittal (BES) to the Deputy Assistant Secretary of Defense (Programming/Budget) (DASD (P/B)). Hearings are held with OSD and the Office of Management and Budget (OMB) and result in Program Budget Decisions (PBD). The PBDs are submitted by DASD (P/B) for the

Presidential Budget with Justification Books sent to Congress. Budgets are reviewed and approved by the Armed Services and Appropriations Committees of both the House and Senate. Discrepancies are worked out by a joint Conference Committee. Projects are approved and funded when the President signs the Appropriation and Authorization Bills into law. Construction funding is requested by the Military Services Headquarters through OSD and OMB and then provided to the construction agent.

If the project was not deleted by the joint Conference Committee, HQ USAF authorizes the Air Force Construction Manager (CM) and the applicable construction agent (CA), either the Army Corps of Engineers (COE) or the Navy Facilities Engineering Command (NAVFAC), to advertise for construction. Opening of construction bids must wait until the bill becomes public law. If bids exceed the programmed amount (PA), the CA can request additional funding from the MAJCOM (if less than 10%), or reduce cost and project scope (if more than 10%). After contract award, and pre-construction conference, the contractor is given a notice to proceed. Construction begins after approval of required submittals.

The contractor is required to warrant workmanship and material for one year. The project manager should perform a post occupancy evaluation after nine to eleven months of beneficial occupancy to identify any defective work. Deficiencies are reported to the CA for correction by the contractor. The project manager should also document any problems and pass this information to the design agent and other project managers to review for similar projects.

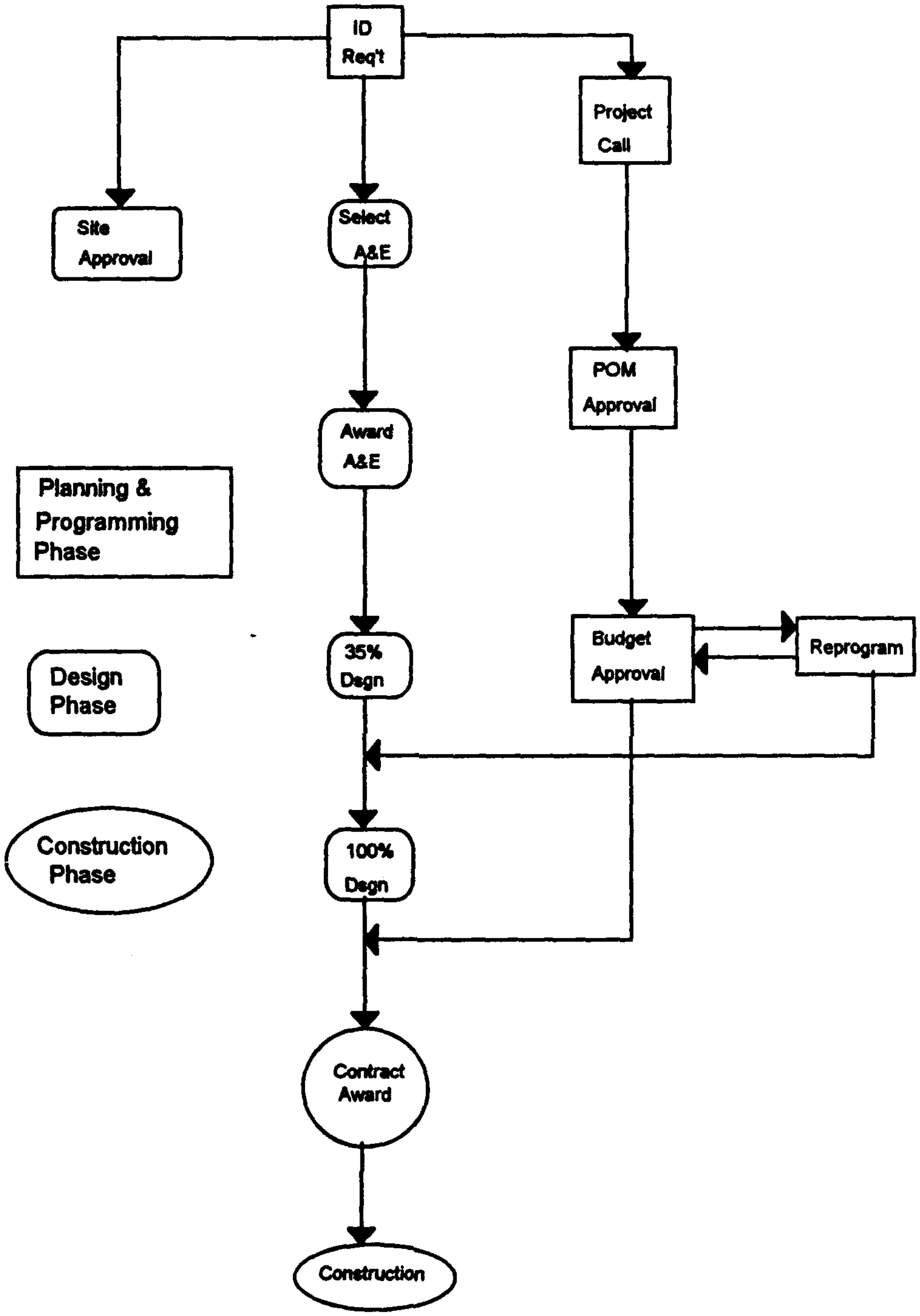


Figure 2.1: MILCON Process Flow Chart

3. Study Methodology

3.1 The Process

Research consists of three basic phases: research definition, research design and testing, and data collection and analysis (Broaddus 91). In definition, a research objective and possible input and output measures are defined, and potential projects and points of contact are identified. In design and testing, initial input and output matrices are developed, and a data survey is designed and fine tuned with the collection and analysis of pilot data, to capture both input and output data. In data collection and analysis, data are collected and project input and output indices are calculated with objectives matrices, corresponding indices are plotted (input index plotted against the corresponding output index for each project), resulting data points are analyzed and conclusions are developed.

3.2 Definition of Inputs and Outputs

Beginning with measures of success and input factors compiled from existing research (Carroll 89; Broaddus 91), a panel of project managers from the construction management directorate of the U.S. Air Force Center for Environmental Excellence (AFCEE) was surveyed to determine and weight appropriate inputs and outputs to measure Air Force construction projects (see Table 3.1 for listing of panel members). The researcher identified project performance, cost variability, schedule performance, and safety as appropriate measures of success from a literature review (Broaddus 91). The researcher also proposed compatible objectives, qualified key leaders, design basis, control systems, project environment, and well defined responsibilities as appropriate factors impacting success from the literature review (Carroll 89).

The surveyed panel adopted the researcher's proposed significant input factors as follows: (1) design basis, (2) qualified key leaders, (3) compatible objectives, (4) well defined responsibilities, (5) control systems, and (6) project environment.

Design basis is the compiled input for the design process. It includes specific processes and facility requirements, project scope, site investigations, design standards, necessary reviews and analyses, etc.

Table 3.1: AFCEE Panel Members

Name	Title
Tanya Banks	Deputy, Medical Division
Dave Cole	Project Manager, Medical Division
Gene Deramus	Designer, Planning & Engineering Division*
Bob Lester	Project Manager, Space Division
Randy Lierly	Project Manager, Space Division
Cleo Walton	Project Manager, Medical Division, Air University

* former project manager

Key leaders, especially the project manager, and general superintendent, can make or break a project. The project manager is responsible for ensuring adequate objectives have been set and that those objectives are met by managing design, procurement, and construction activities. The general superintendent, by how well he plans and coordinates construction field activities, has a tremendous impact on actual construction.

Efforts to define, prioritize, and communicate project objectives through contracts and planning documents, both at the beginning of and throughout a project, are incredibly important to project success. Well established and honest objectives open communication and can address differences and conflicts early to eliminate serious potential problems later in a project. The level of agreement on objectives also sets the stage for the project environment.

The level of effort spent defining responsibilities helps players understand their roles in accomplishing project objectives. This effort can help assign risks to those who can best control them and authority and responsibility to the most qualified people. Establishing clear responsibilities promotes an environment of cooperation and reduces adversarial relationships.

Control systems gather, compile, and distribute data for scheduling, materials, equipment, and facilities management. These systems make it possible to effectively manage the complexity of a construction project.

Perhaps the best predictor of overall project success, project environment includes everything beyond the control of the project manager. Other factors already mentioned have an impact on environment. The degree of agreement on objectives, definition of responsibilities, and level of effective communication and mutual cooperation can impact the project environment. It should be noted that the panel adopted the proposed input factors even though other factors may also significantly impact project success.

The panel adopted the proposed significant measures of success as follows: (1) project performance, (2) schedule performance, (3) project cost variance, and (4) safety. Project performance is how well project objectives are met and how well operating requirements throughout the life of the facility will be met. These will vary for each project, depending on objectives, but may include aesthetics, flexibility, reliability, capacity, and economy of maintenance. The project schedule parameter identifies how well project schedule objectives have been met. Project cost variance is the difference between final project cost and the estimate of project cost at project award divided by the cost estimate at award. Safety performance is an evaluation of the mishap and accident record during construction and the safety problems of the completed facility. For this research effort, accurate safety statistics were not readily available, and safety performance was based on the project manager's rating from the project manager survey. Even though these output measures are widely used and generally accepted, there may be other measures which are equally appropriate to measure construction success.

3.3 Project Selection Considerations

Ideally, large, recently completed projects provide the most significant data. Large projects tend to be more complex and, therefore a better test to determine the most significant input criteria. Recent projects are better for collecting subjective data since key project participants are more likely to be available and data is more likely to be remembered for recent projects.

Projects were selected from the AFCEE Master Project Listing of Military Construction Program (MILCON) projects. For this research, nearly or recently completed projects, most with final construction working estimates (CWE) greater than $2 M, were considered. Smaller projects were included when data became more difficult to obtain. Projects were not selected if project managers had recently taken over management duties and were unfamiliar with either input or output information. The project listing is shown in Table 3.2.

TABLE 3.2: PROJECT LISTING

Location	Project Title	CWE ($000)	PM
ALTUS AFB, OK	FIELD TRAINING FACILITY	4,500	Steck
ANDREWS AFB, MD	ALT MED CTR CLINIC ANNX	2,537	Hughes
BEALE AFB, CA	ADAL POWER PLANT	9,073	Steck
BUCKLEY ANGB, CO	UPGRADE EMRGNCY POWER	7,530	Hodges
GUNTER AFB, AL	STUDENT DORMITORY	3,014	Udall
GUNTER AFB, AL	ADD TO SOFTWARE DEV	6,342	Moore
HOLLOMAN AFB, NM	CONTROL TOWER	3,000	Lester
KIRTLAND AFB, NM	BC-AFISC HEADQUARTERS	13,011	Steck
LACKLAND ANX, TX	ADAL OPERATIONS FACILITY	1,442	Castamore
LITTLE ROCK AFB, AR	HOSPITAL LIFE SAFETY	681	Kivela
MAXWELL AFB, AL	VISITING OFFICERS QRTRS	894	Udall
MAXWELL AFB, AL	ADAL SECURITY POLICE	2,098	Udall
MAXWELL AFB, AL	COMM GROUP	4,800	Udall
MAXWELL AFB, AL	STUDENT DORMITORY	4,822	Udall
MAXWELL AFB, AL	JAG ACADEMIC FACILITY	7,029	Udall
MCCONNEL AFB, KS	COMP HEALTH CARE CLINIC	17,815	Cole
MCGUIRE AFB, NJ	ADAL OPERATIONS/TRAINING	883	Moritz
PATRICK AFB, FL	DINING FACILITY	3,795	Hodges
SCOTT AFB, IL	HQ US TRANSPORTATION	15,200	Steck
SHEPPARD AFB, TX	STUDENT ENLISTED HSNG	8,795	Steck
TRAVIS AFB, CA	ARMED SVCS BLOOD FACILITY	2,029	Cole
YOUNGSTOWN, OH	ADD AVIONICS MAINTENANCE	1,194	Koch

3.6 Data Collection

Data was collected with a project manager survey, and from compiled cost and schedule information. A project manager interview was designed and conducted for these projects over a period of about 12 weeks beginning in the summer of 1993, to collect subjective project data for both output measures and input factors. The survey is included in the appendix. Both input and output data, including a subjective evaluation of cost and schedule goal achievement, were collected from project managers. Managers were asked to rank various aspects of project effort and performance from 1 to 5. The researcher later converted these rankings into scores for the various input factors and output measures. Project managers were individually surveyed via telephone or facsimile and the survey was distributed to individual project managers through Major Tanya Banks, the point of contact at AFCEE at Brooks AFB, Texas. Projects were first selected, and then data were either accepted or rejected depending on the manager's involvement with the project. For the best data, managers were knowledgeable about project planning, design, and construction efforts and were also in a good position to judge project success. The major drawback in collecting both input and output data from one source was the risk of introducing bias. A project which turned out badly could be blamed on inadequate accomplishment of input factors. Separate sources would reduce this sort of bias.

Cost and schedule data were compiled from the AFCEE Programming, Design, and Construction (PDC) database. These data came from the "Key Construction Information" screen, which included the contract amount at award, and the construction current working estimate, which was used to calculate the cost variation score (discussed in Chapter 4), as well as the "contract days" data, the beneficial occupancy dates (estimated and actual), and the construction completion data, which was used to calculate the schedule performance score (discussed in Chapter 4). Some PDC data were, however, difficult to incorporate into this project. The original construction completion date, for example, was usually revised and it was difficult to identify what part of the change was due to "normal" schedule growth and what portion was due to influences outside the project. Although subjective cost and schedule data were compiled from the project manager questionnaire, only the objective data from PDC were used to determine cost growth and schedule growth scores. To convert the raw information into output measures, a table was devised with ranges of raw scores broken down into score values. Raw cost and schedule data conversion information is shown at Appendixes B and C.

3.7 Objectives Matrix Concept

A major challenge of a metrics system is to measure a unique project with multiple criteria of different weights, and compare the results to those of different projects which may have different objectives and criteria. This has been made possible with the application of the objectives matrix. The objectives matrix allows the researcher to gather both objective and subjective data and combine it to produce a single index which can be compared to indexes of other projects (CII Publication 8-1 86). The matrix consists of performance criteria, a performance scale, weights, and the performance index. Performance criteria define what is to be measured. Weights determine the relative importance of the criteria to each other in the overall measurement objective. Criteria and weights must be valid for a matrix to be worthwhile. They can be proposed by a panel of experts, or a larger survey of practicing professionals, but they must be borne out by statistical research. The performance scale compares the measured value to a standard or selected benchmark value. The performance index is calculated by combining each criterion's performance score multiplied by its weight. The performance index is used to indicate and track performance. Example objectives matrixes for measures and input factors are shown in Figure 3.1 and 3.2, respectively.

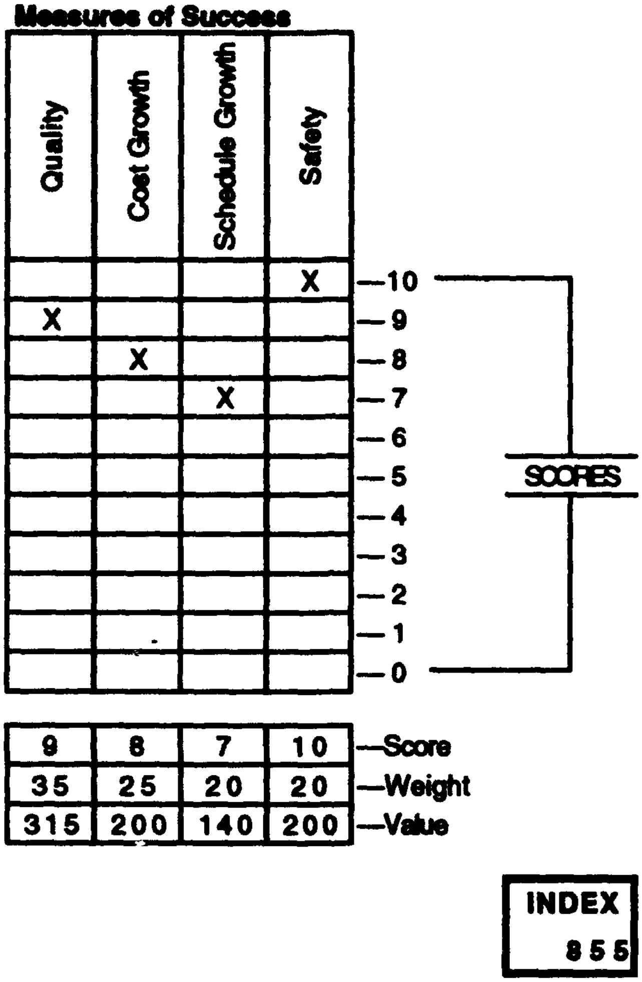
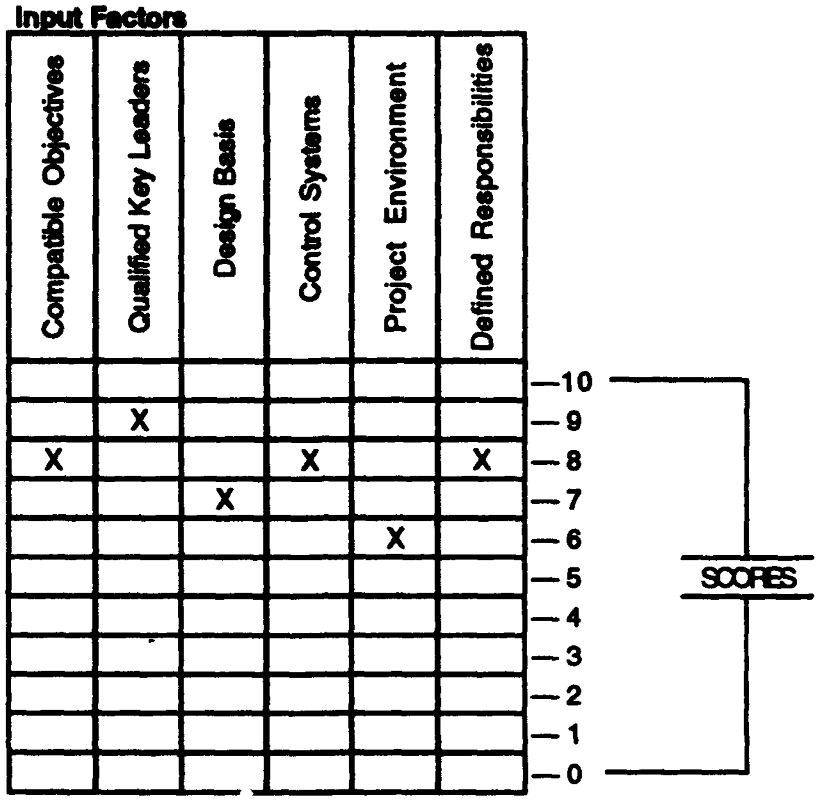


Figure 3.1: Example Output Measures Objectives Matrix



Compatible Objectives	Qualified Key Leaders	Design Basis	Control Systems	Project Environment	Defined Responsibilities	
8	9	7	8	6	8	—Score
15	25	30	10	5	15	—Weight
120	225	210	80	30	120	—Value

INDEX
785

Figure 3.2: Example Input Factors Objectives Matrix

4. Presentation and Analysis of Data

4.1 Overview

This chapter will present project data, including input and output indexes, discuss output index sensitivity to changes in output criteria weighting, compare input and output indexes for each project, and discuss data regression analysis.

4.2 Input Indexes

The AFCEE panel (see Table 3.1) consisting of experienced construction project managers was surveyed to determine input factors and provide factor weights. Panel members were given a proposed list of factors and asked to weight factors on a 100 point scale and also to identify other possible factors. The panel determined the following factors and weights for all projects:

Input Factor	Weight
design basis	30
qualified key leaders	25
compatible objectives	15
well defined responsibilities	15
control systems	10
project environment	5

No additional factors were identified. A description of these factors is included in chapter 3. The same weights were used for all projects to more equitably compare the level of effort which went into accomplishing the project. Arguably, weights could have been changed, depending on the nature of the project, but these factors and weights were viewed as good universal indicators of project effort.

Input factor scores were determined from project manager responses from the project manager interview (see appendix). The design basis factor was calculated by averaging the Project Definition and Design Execution sections of the interview. The qualified key leaders score was determined from responses to the Organization section of the interview. Specifically, the "skills needed to carry out their responsibilities," "key positions changed," and "supported by management" questions. The compatible objectives rating was obtained from the Project Definition section of the interview. The well defined responsibilities rating was taken from the "roles and responsibilities" question in the Organization section. The control systems score was obtained from the "project controls were effective" question in the Construction Execution section. Finally, the project environment score came from the overall evaluation in the Organization section.

Input indexes were calculated with an objectives matrix by multiplying the factor score by the factor weight and totaling them (see Chapter 3 for an explanation of objectives matrices). Each input score was calculated by multiplying the corresponding interview result by two. A factor score of six was considered average, since interview results were based on a five point scale with three considered average. Therefore, an "average" index rating was 600, since factor weights totaled 100. Input indexes ranged from a low of 320 of 1000 possible for the Alter Medical Center Clinic Annex project at Andrews AFB, Maryland, to a high of 970 for the Hospital Life Safety project at Little Rock AFB, Arkansas. Table 4.1 summarizes project input index results.

4.3 Output Indexes

Output measure weights were determined by the same AFCEE panel of project managers (see Table 3.1). Managers were given a list of proposed output measures and asked to weight them on a 100 point scale and identify other possible measures. The panel weighted output measures as follows:

Measure	Weight
project performance	50
cost variability	20
schedule performance	20
safety	10

Table 4.1: Input Results by Project

Location	Project Title	Compatible Objectives	Qualified Leaders	Design Basis	Control Systems	Project Environment	Defined Responsbilities	Index Value
ALTUS AFB, OK	FIELD TRAINING FACILITY	6	9	8	8	8	9	810
ANDREWS AFB, MD	ALT MED CTR CLINIC ANNX	3	3	2	6	4	4	320
BEALE AFB, CA	ADAL POWER PLANT	10	9	8	8	8	8	855
BUCKLEY ANGB, CO	UPGRADE EMRGNCY POWER	6	6	4	6	6	6	540
GUNTER AFB, AL	STUDENT DORMITORY	9	9	8	5	8	8	810
GUNTER AFB, AL	ADD TO SOFTWARE DEV	7	9	7	8	6	9	785
HOLLOMAN AFB, NM	CONTROL TOWER	9	10	8	9	9	8	880
KIRTLAND AFB, NM	BC-AFISC HEADQUARTERS	7	8	6	8	8	8	725
LACKLAND ANX, TX	ADAL OPERATIONS FACILITY	6	6	5	5	6	6	560
LITTLE ROCK AFB, AR	HOSPITAL LIFE SAFETY	10	10	9	10	10	10	970
MAXWELL AFB, AL	VISITING OFFICERS QRTRS	9	8	8	7	8	8	805
MAXWELL AFB, AL	ADAL SECURITY POLICE OPS	8	8	6	7	8	8	730
MAXWELL AFB, AL	COMM GROUP	8	7	8	8	5	6	730
MAXWELL AFB, AL	STUDENT DORMITORY	8	8	8	8	8	8	800
MAXWELL AFB, AL	JAG ACADEMIC FACILITY	8	8	8	6	8	6	750
MCCONNEL AFB, KS	COMP HEALTH CARE CLINIC	10	9	8	6	9	10	870
MCGUIRE AFB, NJ	ADAL OPERATIONS/TRAINING	7	4	6	5	4	6	545
PATRICK AFB, FL	DINING FACILITY	8	8	8	8	10	8	810
SCOTT AFB, IL	HQ US TRANSCOM	6	5	6	5	6	6	565
SHEPPARD AFB, TX	STUDENT ENLISTED HSNG	6	7	7	6	6	6	655
TRAVIS AFB, CA	ARMED SVCS BLOOD FACILITY	9	8	9	6	7	10	850
YOUNGSTOWN, OH	ADD AVIONICS MAINTENANCE	8	8	6	8	9	6	715
	Mean	7.6	7.6	7.0	7.0	7.3	7.4	731
	Standard Deviation	1.7	1.8	1.7	1.4	1.7	1.6	149

Arguably, weights could have been changed, depending on the nature of the project, but these factors and weights were viewed as good universal indicators of results. Project performance scores were obtained from the project manager surveys. Questions about how well the project met anticipated requirements, quality management objectives, operating and maintenance objectives, societal objectives, and the manager's opinion of the overall success of the project were used to arrive at the project performance index. Cost variability was determined from an index of the difference between the construction current working estimate (CWE) and the contract amount at award, divided by the contract amount at award (see Appendix B). These data came from the PDC database. Schedule performance was determined from an index of the revised contract days minus the original contract days scheduled divided by the original contract days scheduled (see Appendix C). Schedule data also came from the PDC database. The safety score was obtained from the project manager questionnaire (see Appendix A). Project managers were asked whether project safety objectives were met or exceeded and responded with their rating of safety performance on a scale of one to five.

Again, the "average" score was considered as six with an "average" project output index of 600 because the interview results were on a one to five scale, with three as the average, and the objectives matrix scores were derived from interview responses. Scores were calculated by multiplying two times the interview response. PDC cost and schedule PDC data were converted to output scores with a scale generated by the researcher. Results of this conversion are shown in Appendixes B and C. Output indexes ranged from a low value of 526 of 1000 possible for the Alter Medical Center Clinic Annex project at Andrews AFB, Maryland, to a high value of 952 for the Hospital Life Safety project at Little Rock AFB, Arkansas. It should be pointed out that the Little Rock project was the smallest in the sample. Table 4.2 summarizes output results.

In general, sample project outputs were very good. The average project performance score was 8.04. The average cost score was 6.86. The average schedule score was 8.04. The average safety score was 8.04. The average output index value for the data was 775. (A project output index of 600 was considered "average.")

Table 4.2: Output Results by Project

Location	Project Title	Quality Score	Cost Score	Schedule Score	Safety Score	Index Value
ALTUS AFB, OK	FIELD TRAINING FACILITY	10	7	6	8	840
ANDREWS AFB, MD	ALT MED CTR CLINIC ANNX	5	5	7	6	550
BEALE AFB, CA	ADAL POWER PLANT	9	1	10	9	760
BUCKLEY ANGB, CO	UPGRADE EMRGNCY POWER	8	1	1	8	520
GUNTER AFB, AL	STUDENT DORMITORY	8	8	9	10	840
GUNTER AFB, AL	ADD TO SOFTWARE DEV	8	6	7	6	720
HOLLOMAN AFB, NM	CONTROL TOWER	8	9	6	9	790
KIRTLAND AFB, NM	BC-AFISC HEADQUARTERS	8	6	10	10	820
LACKLAND ANX, TX	ADAL OPERATIONS FACILITY	8	7	4	8	700
LITTLE ROCK AFB, AR	HOSPITAL LIFE SAFETY	10	8	10	10	960
MAXWELL AFB, AL	VISITING OFFICERS QRTRS	8	8	10	10	860
MAXWELL AFB, AL	ADAL SECURITY POLICE	8	8	8	8	800
MAXWELL AFB, AL	COMM GROUP	7	8	10	7	780
MAXWELL AFB, AL	STUDENT DORMITORY	10	8	7	8	880
MAXWELL AFB, AL	JAG ACADEMIC FACILITY	10	8	8	7	890
MCCONNEL AFB, KS	COMP HEALTH CARE CLINIC	9	6	9	8	830
MCGUIRE AFB, NJ	ADAL OPERATIONS/TRAINING	7	7	6	9	700
PATRICK AFB, FL	DINING FACILITY	8	8	10	10	860
SCOTT AFB, IL	HQ US TRANSPORTATION	6	7	9	6	680
SHEPPARD AFB, TX	STUDENT ENLISTED HSNG	6	9	8	6	700
TRAVIS AFB, CA	ARMED SVCS BLOOD FACILITY	8	9	10	8	860
YOUNGSTOWN, OH	ADD AVIONICS MAINTENANCE	8	7	6	6	720
	Mean	8.0	6.9	7.8	8.0	775
	Standard Deviation	1.3	2.2	2.3	1.5	107

The Alter Medical Center Clinic project at Andrews AFB, Maryland had the lowest quality rating of five. According to the program manager, the facility performed its basic function, but many features could have been much better.

For this project sample, two projects were rated "one," and another rated "five" in the cost criteria when the average performance in this area was 6.86. It should be noted that, although these projects exceeded their original programmed working estimates and were scored low for this evaluation, they did not necessarily exceed their statutory cost limits.

4.4 Output Sensitivity Analysis

The output sensitivity analysis shows how a change in criteria weight affects the output index for each project. This analysis shows how an emphasis in a criterion other than that identified by the panel can affect the overall output index rating, and thus the overall project "success."

Criteria weights were changed to indicate how an emphasis in quality, cost, schedule, or safety affected the project's output index. Output criteria sensitivity was determined by increasing the measure in question to 50 (40 for safety) and holding all others to 20 (10 for safety) and calculating the resulting output index. The "neutral" case was determined by holding all weights at 25. Table 4.3 and Figure 4.1 summarize conclusions.

Output indexes did not change dramatically except for project 3, Adal Power Plant at Beale AFB, California; project 4, Upgrade Emergency Power at Buckley ANGB, Colorado; and project 9, Adal Operations Facility at Lackland AFB Annex, Texas. For these projects, either cost or schedule scores, or both, were significantly lower than other output measures. This indicates how a poor showing in the "hard" measurement areas can impact the project output index when these criteria are stressed.

4.5 Comparison of Input and Output Indexes

Table 4.4 shows the comparison of input and output indexes by project. The input index sample average was 731, and its standard deviation was 149. The output index sample average was 778, and its standard deviation was 105. If the Little Rock AFB,

Table 4.3: Output Sensitivity Results by Project

No	Location	Project Title	"Neutral" Project	"Quality" Project	"Cost" Project	"Schedule" Project	"Safety" Project
1	ALTUS AFB, OK	FIELD TRAINING FACILITY	775	840	750	720	780
2	ANDREWS AFB, MD	ALT MED CTR CLINIC ANNX	575	550	550	610	580
3	BEALE AFB, CA	ADAL POWER PLANT	725	760	520	790	760
4	BUCKLEY ANGB, CO	UPGRADE EMRGNCY POWER	450	520	310	310	520
5	GUNTER AFB, AL	STUDENT DORMITORY	875	840	840	870	900
6	GUNTER AFB, AL	ADD TO SOFTWARE DEV	675	720	660	690	660
7	HOLLOMAN AFB, NM	CONTROL TOWER	800	790	820	730	820
8	KIRTLAND AFB, NM	BC-AFISC HEADQUARTERS	850	820	760	880	880
9	LACKLAND ANX, TX	ADAL OPERATIONS FACILITY	675	700	670	580	700
10	LITTLE ROCK AFB, AR	HOSPITAL LIFE SAFETY	950	960	900	960	960
11	MAXWELL AFB, AL	VISITING OFFICERS QRTRS	900	860	860	920	920
12	MAXWELL AFB, AL	ADAL SECURITY POLICE	800	800	800	800	800
13	MAXWELL AFB, AL	COMM GROUP	800	780	810	870	780
14	MAXWELL AFB, AL	STUDENT DORMITORY	825	880	820	790	820
15	MAXWELL AFB, AL	JAG ACADEMIC FACILITY	825	890	830	830	800
16	MCCONNEL AFB, KS	COMP HEALTH CARE CLINIC	800	830	740	830	800
17	MCGUIRE AFB, NJ	ADAL OPERATIONS/TRAINING	725	700	700	670	760
18	PATRICK AFB, FL	DINING FACILITY	900	860	860	920	920
19	SCOTT AFB, IL	HQ US TRANSPORTATION	700	680	710	770	680
20	SHEPPARD AFB, TX	STUDENT ENLISTED HSNG	725	700	790	760	700
21	TRAVIS AFB, CA	ARMED SVCS BLOOD FACILITY	875	860	890	920	860
22	YOUNGSTOWN, OH	ADD AVIONICS MAINTENANCE	675	20	690	660	660
		Mean	768	775	740	767	775
		Standard Deviation	116	107	139	146	113

Figure 4.1: Output Index Sensitivity to Change in Output Criteria Weight

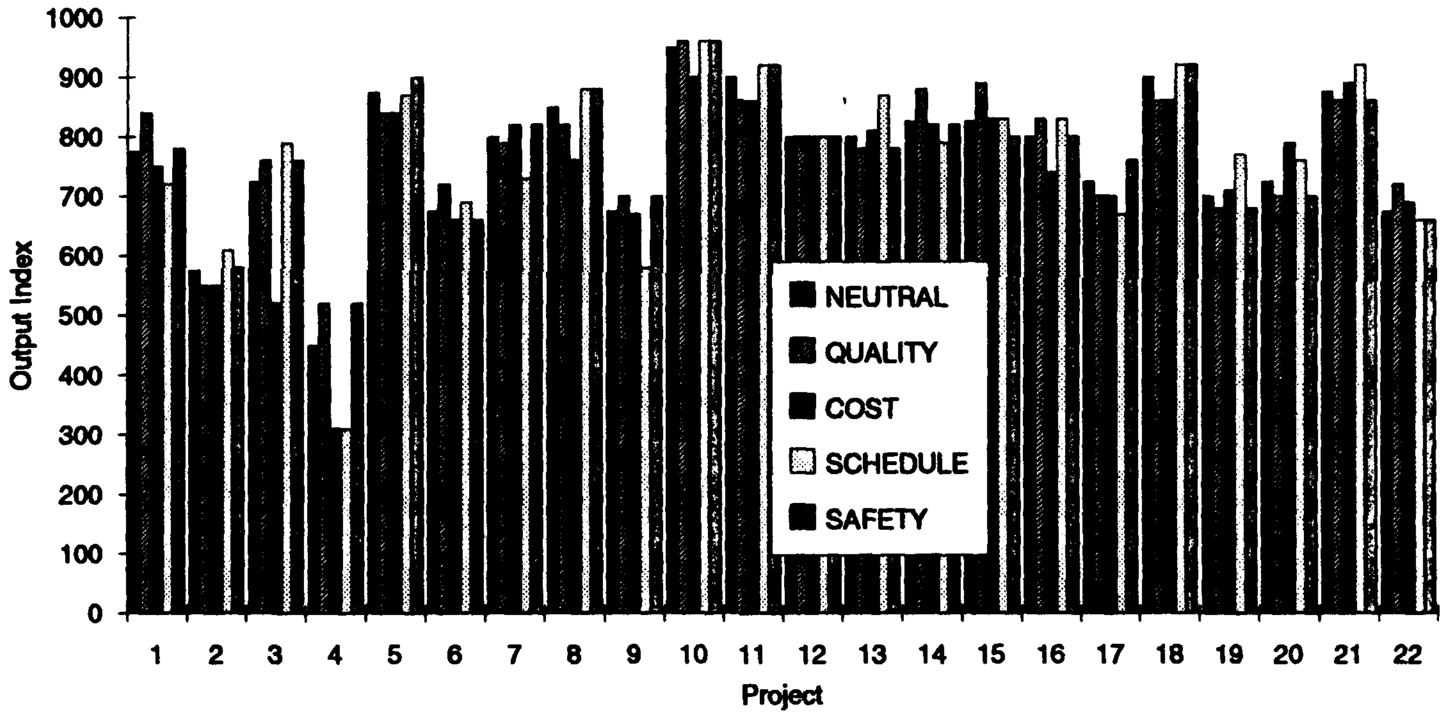


Table 4.4: Comparison of Input and Output Indexes by Project

Location	Project Title	Output Index	Input Index	Absolute Difference
ALTUS AFB, OK	FIELD TRAINING FACILITY	840	810	30
ANDREWS AFB, MD	ALT MED CTR CLINIC ANNX	550	320	230
BEALE AFB, CA	ADAL POWER PLANT	760	855	95
BUCKLEY ANGB, CO	UPGRADE EMRGNCY POWER	520	540	20
GUNTER AFB, AL	STUDENT DORMITORY	840	810	30
GUNTER AFB, AL	ADD TO SOFTWARE DEV	720	785	65
HOLLOMAN AFB, NM	CONTROL TOWER	790	880	90
KIRTLAND AFB, NM	BC-AFISC HEADQUARTERS	820	725	95
LACKLAND ANX, TX	ADAL OPERATIONS FACILITY	700	560	140
LITTLE ROCK AFB, AR	HOSPITAL LIFE SAFETY	960	970	10
MAXWELL AFB, AL	VISITING OFFICERS QRTRS	860	805	55
MAXWELL AFB, AL	ADAL SECURITY POLICE	800	730	70
MAXWELL AFB, AL	COMM GROUP	780	730	50
MAXWELL AFB, AL	STUDENT DORMITORY	880	800	80
MAXWELL AFB, AL	JAG ACADEMIC FACILITY	890	750	140
MCCONNEL AFB, KS	COMP HEALTH CARE CLINIC	830	870	40
MCGUIRE AFB, NJ	ADAL OPERATIONS/TRAINING	700	545	155
PATRICK AFB, FL	DINING FACILITY	860	810	50
SCOTT AFB, IL	HQ US TRANSPORTATION	680	565	125
SHEPPARD AFB, TX	STUDENT ENLISTED HSNG	700	655	45
TRAVIS AFB, CA	ARMED SVCS BLOOD FACILITY	860	850	10
YOUNGSTOWN, OH	ADD AVIONICS MAINTENANCE	720	715	5
	AVERAGES	775	731	74

Arkansas Hospital Life Safety project, the smallest and probably least significant project for this research, is neglected, the input index sample average is 720, its standard deviation is 142; the output index sample average is 770, and its standard deviation is 100. These numbers indicate a much higher than average rating for both inputs and outputs if the "average" project is assumed to rate 500 on both rating scales. The absolute difference column gives a relative idea of how well input indexes and output indexes agree. Some large differences, the Andrews AFB, Maryland Alter Medical Center Clinic Annex project; the Lackland AFB Annex, Texas Adal Operations Facility project; the Maxwell AFB, Alabama JAG Academic Facility project; the McGuire AFB, New Jersey Adal Operations and Training project; and the Scott AFB, Illinois HQ U.S. Transportation project absolute differences suggest some possible environmental factors not taken into account by the questionnaire. The input indexes, except for the Andrews AFB project, are significantly higher than output indexes for these projects, indicating that factors other than those assumed to be critical affected the output rating. This can be partially explained by the way index criteria were weighted for both input and output indexes. The sensitivity analysis section showed the impact of criteria on index values.

4.6 Regression Analysis

A linear regression analysis was accomplished with Microsoft Excel statistical analysis software. Regression uses the "least squares" analysis method to fit a line through a set of observations. Regression is used to analyze how a dependent variable is affected by one or more independent variables. In this case, it is to determine how one independent variable, the input index, affects the dependent variable, the output index. Even though such an analysis may indicate a statistical relationship between variables, it does not necessarily establish a cause-and-effect relationship.

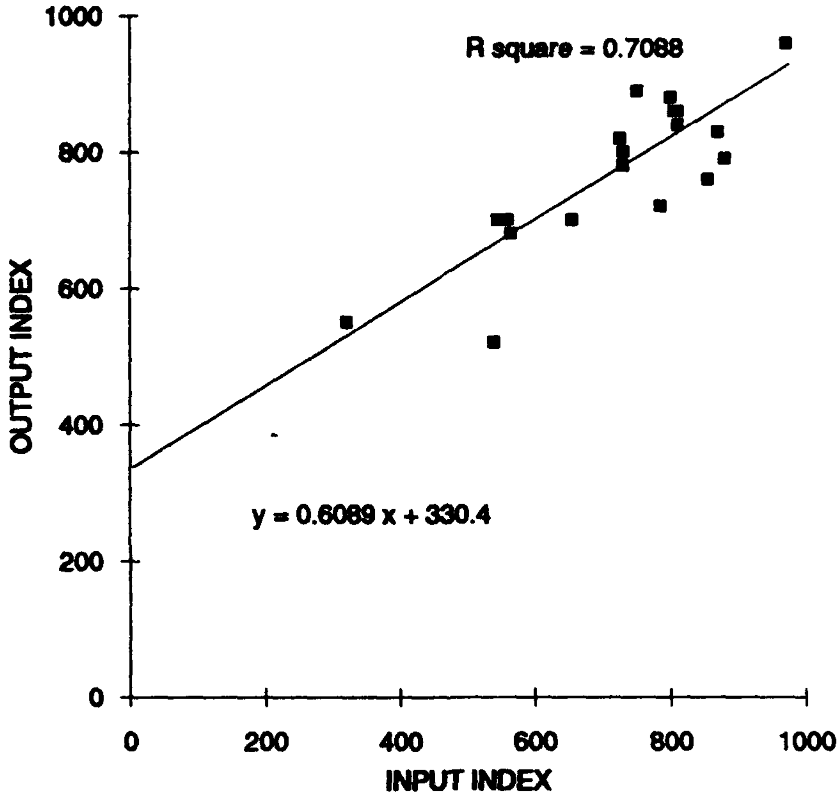
Regression analysis results for the "quality driven" project are summarized in Table 4.5. The corresponding line of best fit graph is shown in Figure 4.2. Correlation coefficients for the other project "types" (see the Output Sensitivity Analysis section) ranged from a low of 0.5819 for the "cost driven" project to a high of 0.8419 for the "quality driven" project. A correlation coefficient of zero indicates no correlation, while a coefficient of one is a positive correlation. This suggests that these data are relatively strongly positively correlated.

Table 4.5: Regression Analysis Results for Quality Driven Project

Regression Statistics	
Correlation Coefficient	0.841878
R Square	0.708758
Adjusted R Square	0.694196
Standard Error	59.40587
Observations	22

	Coefficient	Std Error	t Statistic	Lower 95%	Upper 95%
Intercept	330.4062	65.0377	5.0802	194.7399	466.0724
Input	0.608897	0.08728	6.9765	0.426838	0.790956

FIGURE 4.2: INPUT-OUTPUT INDEX LINE OF BEST FIT



5. Conclusions

Although this investigation involved a relatively small number of projects, three conclusions can be realized from the analyses. These three conclusions are listed below.

1. Relatively high input and output indexes indicate good project management. Input index values averaged 731 and ranged from a low value of 320 for the Andrews AFB, Maryland Alter Medical Center Clinic Annex project to a high value of 970 for the Little Rock AFB, Arkansas Hospital Life Safety project. Output index values averaged 775 and ranged from a low value of 520 for the Buckley ANGB, Colorado Upgrade Emergency Power project to 960 for the Little Rock AFB, Arkansas Hospital Life Safety project.

2. Statistical analyses indicate a strong positive linear correlation between input and output indexes. The input index/output index correlation coefficient for these data was 0.8419 for the weights determined by the AFCEE panel (the "quality" output index). Other weighting combinations resulted in correlation coefficients of 0.7426 for "neutral" output index, 0.5819 for the "cost" output index, and 0.6560 for the "schedule" output index. These coefficients suggest that input index ratings can reliably be used to predict output measures. This analysis alone does not necessarily indicate a cause-and-effect relationship.

3. A reasonable cause-and-effect relationship can be shown by tracing the logic used to design the project manager survey. Input factor statements were designed to determine the level of effort which went into project planning, design and construction. Measures of success statements were designed to determine project results. If both input factors and output measures questions are appropriate, it logically follows that a cause-and-effect relationship has been established. This suggests that it is possible to predict project success based upon input data. Therefore, the objectives matrix evaluation of input factors would be a good predictor.

6. Recommendations

As with any study, two types of recommendations have resulted. First, the study indicates certain activities that are important in project management and organization. Second, further areas for research have been identified.

6.1 Recommendations for AFCEE Action

1. Key leaders: the project manager, construction manager, construction superintendant, and project engineer should be assigned to the project from start to finish. The interruptions, learning curve problems and delays associated with key personnel turnover on projects are unacceptable. In addition, project "ownership," the pride in playing an integral part in a project's success or failure, is lost each time it is handed off.

2. Increased effort should be spent in the planning phase identifying the project objectives of key participants. Team building and formal project objective setting will reduce conflicting objectives and foster improved communication.

3. Design criteria and operational factors should be communicated to the designer. Constructability studies should be included as part of the design process.

4. Roles and responsibilities should be clear. An organization chart should be developed and responsibilities should be specified. Planning meetings and team building should be used to clarify responsibilities.

5. The project information management system should be improved. The existing PDC system reports cost and schedule information, but does little to identify problem areas in a timely fashion. Managers, especially the construction manager, need project schedule, labor productivity, equipment management, and materials management information during project accomplishment to effectively control a project. While this should be done by the contractor, too much is at stake to leave it to chance.

6.2 Further Research

The following areas merit additional study:

1. The results of more concerted planning efforts, including setting formal project objectives, and establishing clear responsibilities.

2. The feasibility of the design and implementation of a new project information management system for construction and project managers.

3. The results of including a constructability study as part of the design.

4. The feasibility and results of maintaining the same key project leaders from project start to finish.

Appendixes

Appendix A: Project Manager Interview

<u>Project</u>
Name
Location

<u>Interviewee</u>
Name
Title Company
Phone Fax

<u>Interview</u>
Scheduled Date/Time:
Actual Date/Time:

This interview should take around 20 minutes. Will this be a problem?

Before we begin, I'd like to read an introduction and answer any questions.

This interview is being conducted to compile data for research on inputs impacting project success. I'm studying aspects of project planning and execution and their impact on overall project success.

Your name and was given to me by of as the representative for the project. For this interview, I'd like to know your opinion on the effort spent planning and executing the project and it's ultimate success. Do you feel qualified and comfortable answering these questions? (If not, someone else?).

The interview is divided into two sections, the first about project success, the second about planning and execution efforts. I'll read a list of statements about the project. I'll ask you to provide a response on a scale of 1 to 5, with 1 meaning you strongly disagree, and 5 meaning you strongly agree. If you have no opinion, please state so.

Your responses will be used only for this research.

Do you have questions before we begin?

Measures of Success

These questions are about the project results. Please use a 1 to 5 scale with 5 meaning strong agreement and 1 meaning disagreement to answer.

1. Project met requirements (objectives). Please comment.

2. Quality objectives.

   a. In general, project participants worked and communicated well together (owners, customers, contractors, managers).

   b. The project was characterized by competent, consistent management.

   c. Emphasis was placed on satisfying the needs of the customer.

   d. Comments:

3. Project control objectives.

   a. Budget objectives were met or exceeded.

   b. Schedule objectives were met or exceeded.

   c. Quality objectives were met or exceeded.

   d. Safety objectives were met or exceeded.

   e. Comments:

4. Planning, and design objectives.

   a. Objectives were well established and agreed upon, especially by client/owner.

   b. Well defined scope contributed to smooth, successful project execution.

c. Constructability and maintainability assessments and lessons learned from other projects were incorporated into the engineering and design phase.

d. Actual project execution (method, controls, schedule, etc.) matched, or nearly matched planned project execution at authorization.

e. Comments:

5. Societal objectives.

a. Regulatory requirements were met or exceeded.

b. Good labor relationship was maintained during construction.

c. Safety and health goals were met or exceeded during execution.

d. Project met EEO goals (minority business, disadvantageB

e. Project met or exceeded community relations goals.

f. Education and training goals were met.

g. Comments:

6. Operating and Maintenance objectives (including ease of transition).

a. Smooth transition from construction to operation.

b. Operational and maintenance requirements were met or exceeded.

c. No major renovation was needed to meet operational or maintenance requirements existing when project was authorized.

d. Comments:

7. What is your overall rating of the success of this project? What are your main reasons for your assessment?

What, if anything, could be improved to make the next project more successful?

Input Factors

The next questions are about the planning, design, and construction effort. Please answer the following questions on the same 1 to 5 scale.

8. Project definition.

a. Project objectives were clear, understood, and agreed upon by all parties.

b. Project scope was well defined at the time the project was authorized.

c. Project risks were identified and evaluated during project planning.

d. Project alternatives were sufficiently identified and evaluated; alternative selection was made by appropriate authority.

e. Project execution plan was well defined during planning stage. (project strategy, i.e. contracting approach, controls systems, scheduling, etc.)

f. Comments:

9. Organization.

a. Roles and responsibilities were clearly outlined and understood. (especially those of key players)

b. Team members had the skills needed to carry out their responsibilities.

c. In general, individuals on the project team worked well together.

d. People in key positions changed frequently (project executive, project manager, general superintendent).

e. Teams were supported by management.

f. Comments:

10. Design execution.

a. Design documents were accurate (drawings and specifications with few or no changes or corrections).

b. Design documents were usable (drawings and specs complete and clear to those using them).

c. Design was constructable. (Project design integrated construction knowledge into planning, engineering, procurement, and field operations to accomplish project objectives.)

d. Design was cost effective. (Design costs, including approved changes, fell within design budget.)

e. Design was efficient. (efficient sizing of members, efficient layout, appropriate tolerances, etc. No "gold plating.")

f. Design and procured materials were delivered within schedule.

g. Project start up was without significant problems (attributable to design).

h. Comments:

11. Construction execution.

a. Project controls were effective. (problems identified early, corrective action triggered, e.g. cost, schedule, quality, safety, materials, labor productivity, equipment, etc.)

b. Qualified, effective construction management.

c. Constructors and craftsmen were qualified, motivated, and effective.

d. Construction methods were effective.

e. Effective supervision and field planning.

f. Effective communication.

g. Minimum construction interference.

h. Minimum changes and rework.

i. *Comments:*

12. What is your overall opinion of the effort put into the planning, design, and construction of this project? *What are your main reasons for this assessment?*

What, if anything, could have been done to improve this effort?

Appendix B: Raw Cost Data Conversion

Converting Raw Cost Variation to Cost Score						
Project	Base	Awd Amt	Cnst CWE	Cost Grwt	Cost Var	Score
FLD TNG	ALTUS	3857	4500	643	17%	7
ALT MED	ANDREWS	2016	2537	521	26%	5
PWRPL	BEALE	4889	9073	4184	86%	1
EM PWR	BCKLEY	4156	7530	3374	81%	1
DORM	GUNTER	2698	3014	316	12%	8
SFTWRE	GUNTER	5167	6342	1175	23%	6
TOWER	HLLOMN	2794	3000	206	7%	9
BCAFISC	KIRTLND	10508	13011	2503	24%	6
ADLOPS	LACKANX	1234	1442	208	17%	7
HOSP LS	LITTLE RK	613	681	68	11%	8
ADAL SP	MAXWLL	1824	2098	274	15%	8
COMM	MAXWLL	4309	4800	491	11%	8
DORM	MAXWLL	4352	4822	470	11%	8
JAG	MAXWLL	6116	7029	913	15%	8
VOQ	MAXWLL	804	894	90	11%	8
HLTHCR	MCNNEL	14690	17815	3125	21%	6
OP/TNG	MCGUIRE	763	883	120	16%	7
DINING	PTRICK	3431	3795	364	11%	8
HQUSTNS	SCOTT	13044	15200	2156	17%	7
ENLHSG	SHPPRD	8096	8795	699	9%	9
WB FAC	TRAVIS	1870	2029	159	9%	9
AV/ECM	WRI-PAT	1755	2054	299	17%	7
AV MNT	YOUNG	1016	1194	178	18%	7

Appendix C: Raw Schedule Data Conversion

Converting Raw Construction Schedule Data to Schedule Score						
		contract days				
Project	Base	original	revised	growth	var	score
FLD TNG	ALTUS	430	518	88	20%	6
ALT MED	ANDEWS	547	634	87	16%	7
PWRPL	BEALE	450	450	0	0%	10
EM PWR	BCKLEY	302	529	227	75%	1
DORM	GUNTER	450	486	36	8%	9
SFTWRE	GUNTER	480	565	85	18%	7
TOWER	HLLOMN	340	408	68	20%	6
BCAFISC	KIRTLND	400	412	12	3%	10
ADLOPS	LACKANX	270	351	81	30%	4
HOSP LS	LTTLE RK	365	374	9	2%	10
ADAL SP	MAXWLL	390	446	56	14%	8
COMM	MAXWLL	480	480	0	0%	10
DORM	MXWLL	540	628	88	16%	7
JAG	MAXWLL	600	660	60	10%	8
VOQ	MAXWLL	50	50	0	0%	10
HLTHCR	MCNNEL	465	503	38	8%	9
OP/TNG	MCGUIRE	365	440	75	21%	6
DINING	PTRICK	480	480	0	0%	10
HQTRNS	Scott	570	615	45	8%	9
ENLHSG	SHPPRD	607	668	61	10%	8
WB FAC	TRAVIS	375	375	0	0%	10
AV/ECM	WRI-PAT	360	514	154	43%	2
AV MNT	YOUNG	270	324	54	20%	6

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Vita

Steven Andrew Davis was born in Meeker, Colorado on October 28, 1961, the son of Verne Lawrence Davis and Bethel Waddington Davis. After graduating from Central High School in Grand Junction, Colorado, he enrolled in Mesa College in Grand Junction. After 2 years of college, he enlisted in the U.S. Air Force. He finished his undergraduate degree in civil engineering at the University of Illinois in Urbana-Champaign through the U.S. Air Force Airman Education and Commissioning Program, and was commissioned a Second Lieutenant in April, 1988.

He served as a design engineer, chief of readiness, and chief of industrial engineering for the 23d Civil Engineering Squadron, England Air Force Base, Louisiana from April, 1988 to May, 1991. He worked as a contract programmer and base community planner at Lajes Field, Azores, Portugal from May, 1991 until he entered the University of Texas at Austin graduate program in August, 1992.

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