CRITICAL SUCCESS FACTORS FOR ENGINEERING AND MANAGING STRATEGIC PROJECTS IN A MANUFACTURING ENVIRONMENT

by

KENNETH LEE MILLER, JR.

Submitted in partial fulfillment of the requirements

for the degree of Doctor of Philosophy

Dissertation Adviser: Dr. Thomas P. Kicher

Department of Mechanical and Aerospace Engineering

CASE WESTERN RESERVE UNIVERSITY

May 1996

UMI Number: 9720437

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

CASE WESTERN RESERVE UNIVERSITY

GRADUATE STUDIES

We hereby approve the thesis of

Kenneth Lee Miller, Jr.

candidate for the Ph.D.

degree.*

(signed) [signature]
(chair)

[signature]

[signature]

[signature]

date November 1, 1995

*We also certify that written approval has been obtained for any proprietary material contained therein.

CRITICAL SUCCESS FACTORS FOR ENGINEERING AND MANAGING STRATEGIC PROJECTS IN A MANUFACTURING ENVIRONMENT

Abstract

by

KENNETH LEE MILLER, JR.

The factors which are most critical to successfully engineer and manage large strategic projects in a manufacturing environment were investigated. Projects in the North American Steel Industry were the primary areas of investigation. A comprehensive literature search revealed industry trends demanding improved efficiency and effectiveness in engineering and managing projects. The search also revealed a weakness in industry specific methods to develop and manage projects in today's complex and dynamic world. To provide focus for this work a classification scheme was devised identifying four basic types of projects encountered in industry, i.e., technology innovation, continuous improvement, business initiatives, and strategic projects. This scheme incorporated key project attributes and suggested appropriate management styles. An expanded definition of project success was developed which

included measures such as safety, project execution efficiency, value perceived by customers, acceptance and use, creation of shareholder value, enhanced market position, and increased organizational competency.

A framework of success factors was postulated as being critical to successfully engineer and manage strategic projects, including;

- Strategic development leading up to project formation
- Clarity of and commitment to project goals and objectives
- Project definition and development
- Project organization and staffing
- Sources of engineering expertise
- Role of leadership in providing vision and alignment
- Customer and end-user involvement
- Work breakdown and supplier relationships
- Project management methodologies
- Risk management

This framework of critical success factors was tested for validation using;

- Retrospective analyses of four major projects recently completed at The Timken Company, ranging in size from $40 million to $450 million.

- Detailed surveys of 18 recent strategic projects completed in the North American Steel Industry, averaging $70 million in size.

The results of these project retrospectives and detailed project surveys confirmed the relationship which certain key factors had with project success or failure. Thirteen of the twenty-three factors probed using the industry survey, were found to correlate with project success to a confidence level exceeding 90%. Consideration of these factors in developing competent project managers and project teams, and implementing large strategic projects is recommended.

Dedication

To my wife Candace and daughters Amanda and Jessica for their love, friendship, support, and extreme patience through the years as I attended graduate school and maintained a full time job.

Also to my parents, Kenneth Miller, Sr. and Alice Miller for tolerating my early mechanical tinkering which inspired my interest in Mechanical Engineering, and for the emphasis which they placed on higher education.

Acknowledgments

This work was made possible by the sponsorship of The Timken Company. The writer would like to thank all of my fellow associates at The Timken Company, with special thanks to;

Tim Timken and Joe Toot for their long term vision and recognition of the importance of science and engineering.

Bob Leibensperger, Chuck West, John Schubach, Sal Miraglia, and Ric Dominik for their continued support and encouragement.

Past project teams at The Timken Company for allowing me to tap their valuable experience base.

The writer would also like to acknowledge the many companies and individuals throughout industry which took part in this research, with special thanks to Davy International, Rust International, Project Management Associates, and the member companies represented by the Project Management Division of the Association of Iron and Steel Engineers.

The writer also wishes to recognize the faculty and staff of Case Western Reserve University for providing excellence in engineering education.

And last but certainly not least, the writer would like to acknowledge and thank Dr. Thomas P. Kicher for serving as advisor to this work, and for his enlightened, insightful, and enthusiastic support.

Table of Contents

Figures

Page

Tables

Page

Chapter 1

Introduction

Background:

The background of this work can best be understood by first examining the trends which have occurred in U.S. Industry, and in particular in the U.S. Steel industry over the last three and one-half decades.

1960's to mid-1970's

The U.S. steel industry experienced strong growth and prosperity during the 1960's and early 1970's. By 1973 and 1974, the growth in the industrialized world had reached a high point, with steel output in the U.S. alone reaching a record level of 136.8 million tonnes[1]. The emphasis through this period was to expand capacity as quickly as possible to keep up with the growing market. There was much less concern during this period over project cost containment or return on investments. Costs were typically passed on to customers with little resistance, therefore as long as a project performed technically, payback was virtually guaranteed. Projects were typically developed and executed with sequential hand-offs between functional departments such as Marketing, Capacity Planning, Engineering, Manufacturing. Companies built up large internal engineering staffs to design and install new facilities. Outside suppliers were typically limited to supplying equipment, not engineering, project management, or turn key contracts.

Mid-1970's through 1980's

During the mid 1970's, U.S. manufacturing companies were forced to face major economic challenges. In 1975, U.S. steel production fell 20% to 105.8 million tonnes. The 1970's saw increased oil prices engineered by OPEC, soaring interest rates, and a major market contraction due to an industry wide recession. While the market recovered slightly in 1978 and 1979, the recovery was short lived. The incredible string of 35 consecutive profitable years, during the post-World War II period, was abruptly snapped in 1982 when the industry fell into a deep depression and U.S. steel output dropped to a mere 67.7 million tonnes.[2] In contrast, during this same period, steel production in Third World countries such as Brazil, South Korea, China, Taiwan, and Mexico grew at an explosive rate. This increase in foreign competition and shrinking markets drove income statements into the red. Advances in process technology spawned new low-cost mini-mill entrants, putting even further pressure on the traditional U.S. stee! industry. Negative cash flow was experienced for the first time in many modern U.S. companies, and its effect was compounded by the increased cost of borrowing. Most investments were limited to mandated environmental compliance projects and cost reduction efforts. A by-product of these economic pressures was an increased sensitivity to project cost control and payback. In addition, many U.S. Steel companies significantly reduced the size and scope of their research and development efforts, as well as their internal engineering departments.

1990's and beyond

Intensity of global competition continued to escalate in the early 1990's. Competition and increasing customer performance demands have dictated a need for investments in new technology. Retrofitting new technology into existing plants has become an important strategy and has reduced the capital intensity of many projects. Project execution must now be critically linked with market objectives and financial returns. Greater need has emerged for up-front strategic planning prior to launching projects. Compressing investment payback periods through accelerated project execution has become essential. Steel companies have continued to reduce their engineering staffs and have increased their focus on activities core to their businesses, e.g., marketing and manufacturing. Trends toward turn-key projects, engineering partnerships, and virtual project teams continue. The supply base for the most advanced technology and equipment is continuing to expand globally. An explosion of computer software and new telecommunications media has dramatically altered project management and communication methods. The U.S. industry has experienced some relief from foreign competition in the mid-1990's as a result of the weakened U.S. dollar and recent improvements in labor productivity. However given the worldwide market dynamics and industrial growth, the U.S. steel industry must enter the twenty-first century with sound business strategies and an aggressive attitude towards continuous improvement.

Introductory Definitions

Definition of a Project

Webster defines a project as "a specific plan, design or scheme devised or proposed for which there seems hope of success".[3] Shenhar adds the concept of resource allocation, by defining a project as "a temporary organization of resources to accomplish a specific objective."[4] Kerzner adds the concept of specifications and constraints by defining a project as "a series of activities and tasks that have a specific objective to be completed within certain specifications, have defined start and end dates, have funding limits (if applicable), and consume resources (money, people, equipment)."[5] Companies use projects as temporary organizational structures to accomplish change. Mechanical engineers as well as virtually all other engineering professionals apply their knowledge to practical purposes through conducting projects. Engineers working in design, product development, basic research, or manufacturing typically complete their individual work in a project format or serve with others on a project team for larger efforts. The size and scope of projects can vary considerably.

Definition of Project Management

Kerzner defines project management as "the planning, organizing, directing and controlling of company resources for a relatively short term objective that has been established to complete specific goals and objectives. Furthermore, project management utilizes the systems approach to management by having functional personnel (vertical hierarchy) assigned to a specific project (horizontal hierarchy)."[6] Formal project management techniques are relatively new compared to the broad field of engineering. They were first introduced in large government related projects and in the construction industry. New applications of project management have grown since that time. The United States leads all other nations in the use of formal project management techniques, which can be attributed to the highly developed defense related industry, and construction industry.

Formal Projects Teams Are Becoming A More Prevalent Organizational Scheme.

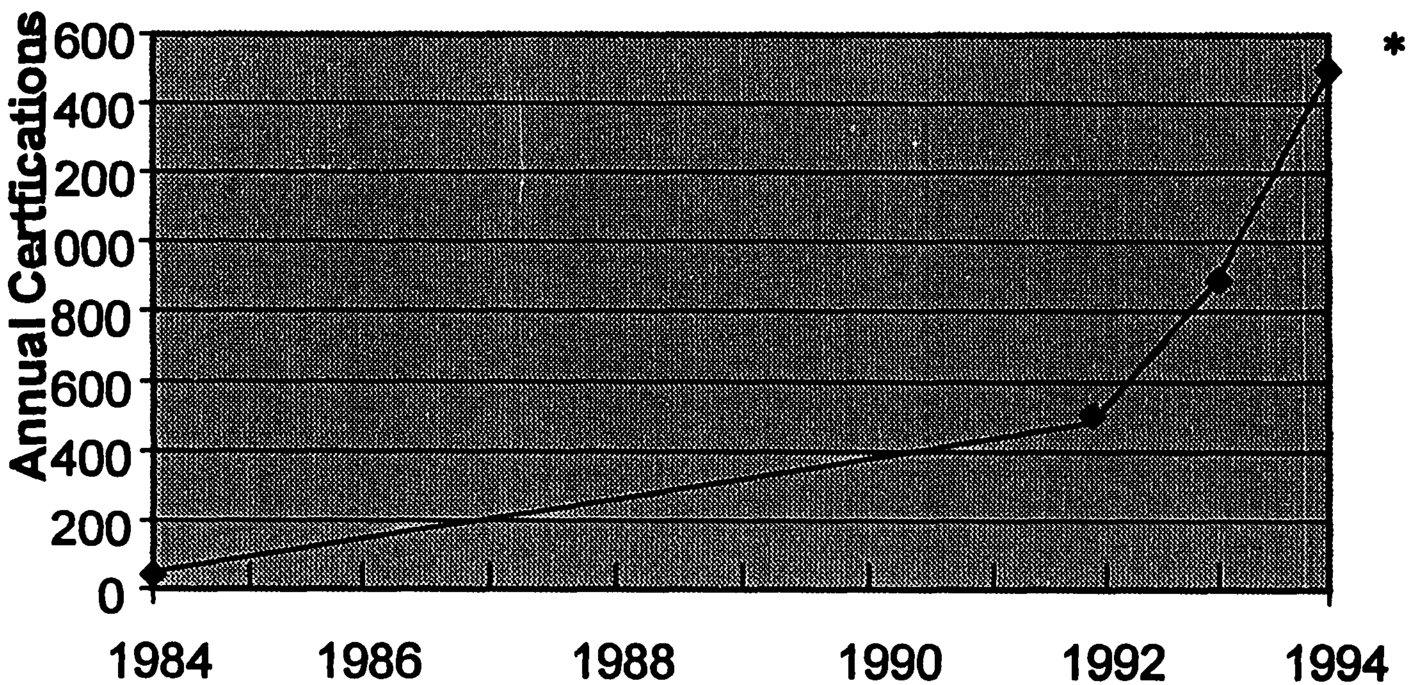
Companies are increasing their use of projects and project teams as an organizational structure to accomplish change and drive continuous improvement.[7] There is evidence that some companies are replacing their more traditional functional organizations with more project oriented management structures. Similar to a matrix structure, a project oriented management structure is extremely flexible, a characteristic which is important in today's dynamic world. A team of people with unique talents and skills can be assembled to meet a specific set of project objectives.

Relevance to Engineering Profession

With this increasing trend, it is more important than ever for companies to learn how to establish and support effective project teams, and for engineers to develop project engineering and project management skills. The need for formal project management skills has spawned a new professional registration, administered by the Project Management Institute. As can be seen in Figure 1.1, since the first 41 certifications issued in 1984, the number of professional project managers certified annually has grown to 1500.[8] It should be noted that projects can have varying levels of technical complexity and are not confined to the engineering or scientific communities. However, virtually all engineers will at one point in time, be assigned to a project team or most likely to lead a project as the project manager.

Number of Project Manager Certifications Issued by Project Management Institute

Figure 1.1



Source: PMI 1995

* 1994 Estimate

Limitations of Academic Treatments of Project Management.

Most academic treatments of project management present methodologies in a general sense and do not tailor them to a specific type of project or industry. Project Management methods such as critical path network methods provide excellent tools to aid in project management. This is a highly developed field with an abundance of references detailing project management methods.[9,10,11] Engineering students taking a course in project management will undoubtedly study the various methods of estimating time duration, drawing precedence diagrams, determining critical paths, leveling resources, and tracking project costs. These methods are very beneficial in planning, organizing, and tracking the progress of most projects, and their application should be encouraged. Such project management methods alone however, do not prepare an engineer to be an effective project engineer or project manager. Many other skills, styles, and work methods are required to be an effective project manager. Little formal research has been conducted on these additional requirements, and even less is available to engineering students or young practicing engineers to prepare them for project management assignments. Typically these skills are acquired through on-the-job training by starting out on small projects and elevating to larger more complex or costly projects. This approach takes time for engineers to develop these skills, and often results in learning curve mistakes along the way. The traditional "apprenticeship" methods for learning these skills are disappearing. Companies are leaning out their staffs, shifting away from functional organization models with their rigidly defined methodologies, and are moving to flatter organizations offering less oversight to younger engineers. With today's rapidly changing business environment and fierce competition it is difficult to simply accept major mistakes or delays in projects as a "learning experience". The second deficiency with these traditional project management methods is that they do not provide guidance to help companies better organize project teams and develop their engineers to become effective project leaders. These methods do not address the actual dynamics which occur as projects are conceived, planned, executed, and concluded in a manufacturing environment.

Objectives of this dissertation

The objectives of this research are to develop a framework which classifies the variety of projects occurring in a manufacturing environment, and to identify the factors which are most critical to successfully engineer and manage large strategic projects. The research has special emphasis on the steel industry.

This work analyzes the nature of projects and methods, both successful and unsuccessful, which have been applied in a manufacturing environment. Classification schemes are devised to help engineers and corporations recognize the distinctions between different types of projects. Theories are developed on critical success factors. Project Management styles and methods will be put forward which are contingent to the type of project as well as critical success factors. The two types of projects of primary interest will be continuous improvement in nature and strategic projects. Trends in project management will be analyzed and corresponding methods to deal with these distinct project types will be developed. Finally a framework of methodologies will be introduced to supplement the more traditional project management methodologies. This work will be useful to young engineers as they enter industry, but also to more advanced professionals taking on more challenging projects, and to corporations in their efforts to develop engineers capable of leading effective projects, and to organize and support effective project teams.

Overview of Methodology

The methods and procedures used to conduct this research were to begin with a comprehensive literature review followed by a "self-debriefing" intended to relate findings on this topic from the author's personal project experience. This background served as a basis to first classify various types of projects, and second to define an appropriate framework for project success factors. This framework was then tested as a hypothesis by analyzing other projects within The Timken Company as well as extensive research into recent large strategic projects completed throughout the steel industry. The most significant "Critical Success Factors" for these projects were identified through a statistical analysis of the external research data, and then summarized as a set of final recommendations.

References - Chapter 1

[1] Hogan, S.J., William T., "Global Steel in the 1990's," Lexington Books, 1991

[2] Hogan, S.J., William T., "Minimills and Integrated Mills," Lexington Books, 1987

[3] Webster, "Third New International Dictionary", 1961

[4] Shenhar, A. J., "Project Management In Modern Organizations", 1995

[5] Kerzner, H., "Project Management, A Systems Approach to Planning, Scheduling, and Controlling," Van Nostrand Reinhold, 1992

[6] IBID (5)

[7] Kohrs, R. H., "The Impact of Flattening of the Corporate Organization - A New Role For Project Management", Project Management Proceedings, October 1993

[8] Project Management Institute, Upper Darby, Pa.

[9] Barrie, D. S. and Paulson, B. C., "Professional Construction Management," McGraw-Hill, 1978

[10] O'Brien, J. J., "CPM in Construction Management," McGraw-Hill, 1993

[11] Humphreys K.K., and English, L.M., "Project and Cost Engineers' Handbook," Marcel Dekker, 1993

Chapter 2

Hypothesis and Context

As described in the introduction the first step of this research was to conduct a comprehensive review of project engineering and project management literature. This review was followed by a "self-debriefing" intended to relate findings on this topic from the author's recent experience as Project Manager of a series of large strategic projects at The Timken Company. The initial scope of these projects totaled $170 million and included a new continuous casting facility capable of producing high quality engineering and bearing steels, a precision bar rolling mill, two new bar inspection facilities for small and intermediate sized alloy bars, and expansion of Faircrest, a state-of-the-art steelmaking facility. This project experience included early strategic development, process technology development, project implementation, and facilities startup.

This literature search and project background was then used to develop a framework for project critical success factors. This framework was later tested as a hypothesis by analyzing other projects within The Timken Company as well as extensive research into other recent projects completed throughout the steel industry.

Before constructing this framework, it was necessary to develop a definition for Critical Success Factors, Strategic Projects, and Project Success. These definitions also played an important role in testing the validity of this framework.

Critical Success Factors

Critical Success Factors (CSF) are those factors which when present, significantly improve the likelihood of success for a given activity, and conversely when absent significantly increase the odds of failure. CSF's could in theory be developed for virtually any field. The use of CSF's were initially discussed by Daniel in 1961 as he examined the Management Information Crisis.[1] Anthony, Dearden, and Vancil later utilized the concept in the design of a management control system.[2] In 1979 Rockart applied the approach to define the CEO and General Manager's needs for information.[3] Leidecker and Bruno, then applied the technique in 1984 to the area of strategic planning and business strategy development. Here, they defined CSF's as "those characteristics, conditions, or variables that when properly sustained, maintained, or managed can have a significant impact on the success of a firm competing in a particular industry."[4] Cleland and Kerzner more recently applied the notion of CSF's in their research into the best managed projects.[5] Using the results of extensive company interviews, Cooper identified success factors which are critical to developing and launching new products.[6]

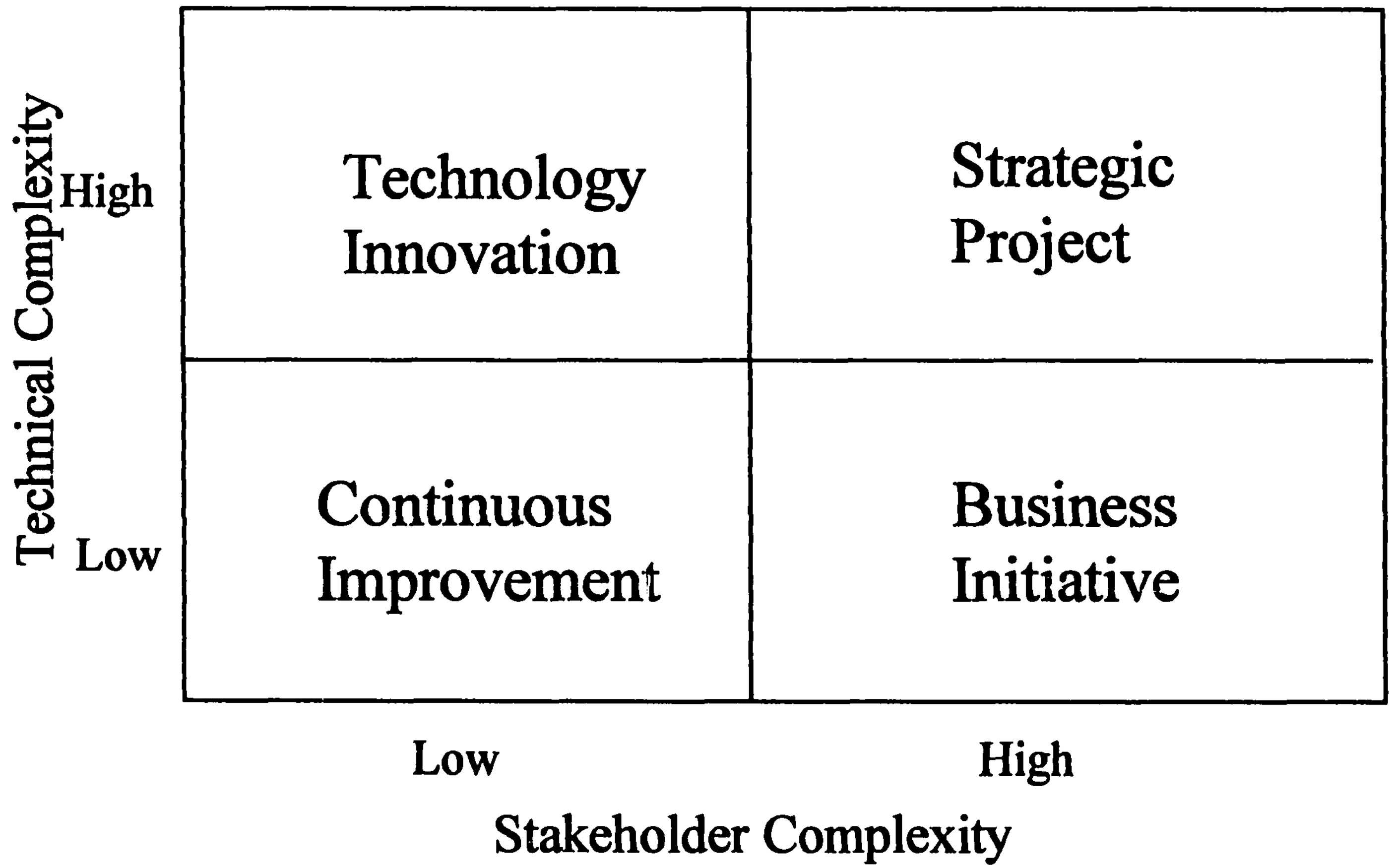
Strategic Projects

For the purposes of this research, ***Strategic Projects*** have been defined as large scale projects with significant technical challenge and financial risk, impacting a broad range of stakeholders, and typically spanning several years from initial concept and business analysis to completion and startup.

To further characterize strategic projects, the author has developed a Project Classification Matrix shown in Figure 2.1. In this scheme, projects are classified using the dimensions of "technical complexity" and "stakeholder complexity". Technical complexity refers to the level of sophistication, challenge, and risk associated with the technologies being employed on the project. Stakeholder complexity refers to the magnitude of constituents having a vested interest in the project, whether as a supplier, customer, end user, shareholder, community member, government official, senior corporate manager, or project team member. The sheer number and diversity of these constituents as well as their organizational and geo-political relationship to the project, all contribute to the degree of stakeholder complexity.

Project Classification Matrix

Figure 2.1



The author utilized this classification matrix and the following definitions to further characterize four distinct types of projects:

Technology Innovation:

Projects with high technical complexity but limited stakeholder complexity.

Continuous Improvement:

Projects with limited technical complexity and limited stakeholder complexity.

Business Initiatives:

Projects with low technical complexity but high stakeholder complexity.

Strategic Project:

Project with both high technical complexity and high stakeholder complexity.

The attributes of these four sub-types are further identified in Table 2.1. Here the author defines project characteristics and projects typical of each category.

Such a project classification tool can be valuable in deciding the approach which should be used to develop and manage a given project. Shenhar developed the concept of "A Contingent Project Management Approach".[7] The author has extended Shenhar's concept and applied it to these four project types. Suggested in Table 2.2 are contingent project organizational and manager requirements, and planning and management styles.

Project Classification Attributes

Table 2.1 -

Project Type (Variable)	Continuous Improvement	Business Initiative	Technology Innovation	Strategic Project
Technical Complexity	**Low**	**Low**	**High**	**High**
Stakeholder Complexity	**Low**	**High**	**Low**	**High**
Project Characteristics	Limited technical risk. Narrow Single Operation or Department affected	Non-technical in nature. Very Broad Areas impacted inside and outside of the company	High Technical Uncertainty and Risk. Limited and Narrow business impact of project at this stage.	Significant Technical challenges and risks. Involving or impacting a wide range of associates inside and outside of company
Typical Projects	Continuous Improvement, Redesign of operating procedures. Manufacturing cost reduction. Incremental product quality enhancement.	Redesign of business systems and practices. Marketing initiatives. Organizational Redesign.	Fundamental Research and Discovery. Major Product or Process Innovations.	New product launch or major redesign. Major Capital Expenditures on New Manufacturing Facilities.

Contingent Project Management Styles

Table 2.2

Project Type (Variable)	Continuous Improvement	Business Initiative	Technology Innovation	Strategic Project
Project Manager Requirements	Action-oriented. Knowledge of local operation.	Strong leadership skills. Demonstrated knowledge of business.	Functional Expert, Conversant and familiar with cross functions	Broad technical, business, financial, strategy, and marketing knowledge.
Project Organization	Local management of project with part time assistance from functional departments.	Full time project manager with strong business orientation. Part/full time support.	Focused, dedicated technical associates assigned to project	Full time "Tiger" team, highly cross functional, autonomous, frequent contract with Sr. Management and Customers
Planning	Simple, direct. Limited analysis and external environmental assessment. Shorter planning time horizon.	Risk analysis, Lots of communications. Involve stakeholders during planning	Technical Feasibility. Work plan is phased due to high uncertainty. Flexible schedules and resources requirements.	Risk Analysis, Risk Mgmt. Contingency Planning. Test marketing or prototyping where possible. Rigorous strategic analysis and business case development. Firm schedules & milestones established.
Management Style	Informal, firm deadlines, autonomous, action oriented, fast decision making, few layers. Well defined approval hurdles.	More bureaucratic, increased formality, multiple approvals	Rigorous scientific methods used. Proper documentation.. Formal reporting of progress.	Highly structured, formal, monitoring of progress against established milestones and budgets. Formal change management involving customers.

Project Success

In order to construct a framework for project critical success factors, it is necessary to first define what is meant by project success. The current literature frequently refers to a narrow view of project success as meeting the scope, quality, schedule, and budget of the project. Kerzner adds the dimension of maintaining "good customer relations" as an important additional element to project success.[8] More recent work by Pinto and Piscott expanded the view of project success to take into account the importance of end-user's and customer's perception of project success.[9]

The writer's personal observation is that a more comprehensive definition of project success is needed. Success should account for other important dimensions which distinguish excellence in today's competitive marketplace and the need to ensure the safety and development of our associates. The author's view of the most important measures of project success are illustrated in Table 2.3.

Project Success Measures

Table 2.3

Project Success Dimension	Measure	Comprised of	As perceived by
Efficiency	Safety	Project safety goals met for construction and operation of facility. Complete environmental compliance.	• Project Team • Constructors, End Users and their families • Governmental Agencies, e.g. OSHA, EPA
	Project Execution	Conformance to scope, quality, schedule, cost, legal requirements.	• Project Team • Executive Sponsor
Effectiveness	Perceived Value	Creation of value for customers, or for customers' customers.	• Customers (Internal) • Customers (External)
	Acceptance and Use	Acceptability to end users and customers, and actual usefulness.	• End Users • Customers
	Creation of Shareholder Value	Positive impact on financial performance and profitable growth of the business enterprise.	• Shareholders • Board of Directors • Investment Community
	Enhanced Market Position	Enhanced product leadership, cost competitiveness, quality reputation, size and influence.	• Industry at Large
Growth Through Learning	Increased Competency	Increased technical, organizational, social, project engineering and management skills. Broadened understanding of the business, customer values, and key financial drivers.	• Project Team • Executive Sponsor • End Users • Senior Management

Framework of Critical Success Factors

From personal experience and literature findings, the author postulated a set of factors considered of critical importance to engineering and managing strategic projects. In order to better illustrate these factors, the author has incorporated them into a framework adapted from the frequently referred to McKinsey 7-S framework. This framework was presented in the book, "In Search of Excellence " which was based on research into some of America's best run companies.[10] The "7-S" framework was developed as a means of visualizing the critical elements of effective organizations. While a project is only a temporary organization of resources, it is nonetheless an organization and therefore the 7-S framework was found to be highly relevant.

Proposed Critical Success Factor Framework For Engineering and Managing Strategic Projects.

"Hardware"

Strategy

- Strategic Development Leading up to Project Formation [11,12]
- Benchmarking [13]
- Project Definition, Planning, Goal Definition [14,15,16]

Structure

- Project Team Structure [17]
- Work Breakdown Structure [18,19]
- Contract Structure [20,21]

"Software"

Staff

- Project Manager Skills [22,23]
- Project Team Selection [24,25]

Shared Values

- Vision [26,27]
- Team Building and Alignment [28, 29, 30]
- Commitment to Project Goals [31,32]

Systems

- Project Management Methods [33,34,35]
- Risk Analysis and Management [36]
- Specifications and Standards [37]

Skills

- Engineering Expertise [38]
- Supplier Qualifications
- Training of End Users [39]

Style

- Senior Management Support for Project [40,41]
- Communications [42,43]
- Stakeholder Involvement (Customers, Investors, End-users) [44,45]
- Empowerment of Project Team [46,47]
- Risk Taking (Stretch) [48]

Now that these key success factors have been proposed and organized into this conceptual framework, it was necessary to test their importance. The author will describe the methodology used to test the framework's validity in the following chapter.

References - Chapter 2

[1] Daniel, D.R., "Management Information Crisis," Harvard Business Review, Sept-Oct 1961, pp. 110-119

[2] Anthony, R.N., Dearden, J., and Vancil, R.F., "Key economic variables, in Management Control Systems," Irwin, Homewood, Illinois (1972) pp. 138-143

[3] Rockart, J.F., "Chief Executives define their own data needs," Harvard Business Review, March-April (1979) pp. 81-92

[4] Leidecker, J.K. and Bruno, A.V. "Identifying and Using Critical Success Factors," University of Santa Clara, Long Range Planning, Vol. 17, No. 1, 1984, pp. 23-32

[5] Cleland, D.I. and Kerzner, H., "The Best Managed Projects," 1985 Proceedings from PMI Symposium, October 1985 pp. 1-24

[6] Cooper, R.G., "Winning at New Products" Addison-Wesley 1994, pp. 75-94

[7] Shenhar, A.J. and Dvir, D., "Proceedings of the 28th Annual Hawaii IEEE International Conference on System Sciences," 1995, pp. 494-503

[8] Kerzner, H., "Project Management, A Systems Approach to Planning, Scheduling, and Controlling," Van Nostrand Reinhold, 1992

[9] Pinto, J.K. and Piscott, J.E., "Planning and Tactical Factors in the Project Implementation Process," Working Paper 89-07, University of Maine, December 1988

[10] Peters, T.J. and Waterman, R.H., "In Search of Excellence, Lessons form America's Best-Run Companies," Warner Books 1982 pp. 11

[11] Porter, M.E., "Competitive Advantage, Creating and Sustaining Superior Performance" The Free Press, 1985

[12] Strategic Management - Internal Timken Document

[13] Camp, R.C., "Benchmarking," Quality Press, 1989

[14] Hatch, G.G., Noskiewicz, T.M. and Goode, J.D., "Top Management and Capital Spending Projects," TMS Paper No. A74-90, 1984

[15] Wideman, R.M., "A Framework for Project and Program Management Integration," PMI, 1991

[16] Blanchard, F.L., "Engineering Project Management," Dekker, 1990

[17] Hayes, R.H., Wheelwright, S.C. and Clark, K.B., "Dynamic Manufacturing, Creating The Learning Organization," The Free Press, 1988

[18] IBID (16)

[19] IBID (8)

[20] Marsh, P.D.V., "Contracting for Engineering and Construction Projects," Gower-Ashgate Publishing, 1988

[21] Bates, G.D., "Becoming an Effective Negotiator," Roenker Associates, 1991

[22] Adams, J.R. and Campbell, B.W., "Roles and Responsibilities of the Project Manager," Project Management Institute, 1990

[23] Kotter, J.P., "A Force For Change, How Leadership Differs From Management," The Free Press, 1990

[24] Wellins, R.S., Byham, W.C. and Wilson, J.M., "Empowered Teams," Jossey - Bass Publishers, 1991

[25] Martin, D., "Teamthink," Dutton, 1993

[26] Barker, J.A., "Discovering The Future," ILI Press, 1989

[27] IBID (23)

[28] IBID (25)

[29] Francis, D., Young, D., "Improving Work Groups, A Practical Manual for Team Building," Pfeiffer, 1991

[30] Lewins, K., "Frontiers in Group Dynamics" Human Relations, Vol. 1, No. 1, 1947

[31] Brockbank, W., Seminar Notes, University of Michigan, 1994

[32] Rockwell International, Internal Trip Report, 1990

[33] Barrie, D. S. and Paulson, B. C., "Professional Construction Management," McGraw-Hill, 1978

[34] O'Brien, J. J., "CPM in Construction Management," McGraw-Hill, 1993

[35] Humphreys K.K., and English, L.M., "Project and Cost Engineers' Handbook," Marcel Dekker,1993

[36] Wideman, R.M., "Project and Program Risk Management," Project Management Institute, 1992

[37] Project Specifications and Standards - Internal Timken Documents

[38] Thamhain, H.J., "Engineering Management," Wiley-Interscience, 1992

[39] Mager, R.F., "What Every Manager Should Know About Training," Lake, 1992

[40] IBID (8)

[41] Block, R., "The Politics of Projects," Yourdon Press,

[42] Fiechtner, S.B., "Improving Managerial Communication Skills," Communication Development Associates, 1991

[43] Brooks, F.P., "The Mythical Man-Month," Addison-Wesley

[44] IBID (9)

[45] Whiteley, R.C., " The Customer Driven Company," Addison-Wesley, 1991

[46] IBID (23)

[47] IBID (24)

[48] Schaffer, R.H., "The Breakthrough Strategy," Ballinger, 1988

Chapter 3

Testing Methodology

In the previous chapter, a Project Critical Success Factor Framework, developed from literature findings and the author's personal experience, was introduced as a hypothesis. In order to test this hypothesis, the author engaged several additional sources of information. These sources were, Timken senior management, former Timken project teams, external senior level engineering managers and project managers, and senior level managers of large external engineering and construction companies. The formats used to gather this information included group brainstorming meetings, structured written surveys, personal one-on-one interviews, and telephone interviews. In each case, the author utilized a "Critical Incident Technique (CIT)" to gather the information.[1] The early roots of CIT date back to the 1870's when Sir Francis Galton developed techniques to study human behavior. Formal use of CIT really began during World War II as an outgrowth of the U.S. Aviation Psychology Program. The purpose was to study specific reasons that pilot candidates were being eliminated from flight training schools. From this research, more objective criteria were established for the type of candidates and development needed to ensure better success rates. The earliest industrial application of CIT occurred in 1949 with a study by Finkle at Westinghouse Electric on the performance of foreman.

The premise of CIT is that reporting of facts regarding behavior is preferable to the collection of interpretations, ratings. and opinions based on general impressions. In the case of this research into project management, the author's objective was to interview people on real life project experiences, rather than hypothetical circumstances or opinions. In this case, the given project or specific event during the project would be the critical incident which would be analyzed. The individual and group interviews were to learn what behaviors, activities, and techniques contributed positively to the success of specific projects, and what contributed negatively to specific projects. From this, one can predict future behavior which will be helpful in managing large strategic projects. This is both in regard to the project manager's role in leading the effort and that companies role in developing the project and supporting it with resources.

Internal Testing

The author first applied this CIT technique to test the CSF framework against other project experiences within The Timken Company. Several members of Timken senior management were interviewed to gain a top-down view of strengths and weaknesses in the methods used to conceive, develop, engineer, and implement projects. Next, "retrospective analyses" were conducted on a number of large capital projects recently implemented within the Steel and Bearing Divisions of The Timken Company. These projects, which averaged $160 million in size, involved extensive use of advanced manufacturing technologies and computer systems. The retrospectives involved meeting with key members of the project teams responsible for the respective projects. General timelines for each project were recreated noting the most significant project phases, milestones, and key decision points. The groups were then asked to respond to a number of questions regarding methodology, key success factors, and factors which contributed to less than desired results. This resulting information was then summarized and compared with the CSF framework introduced in Chapter 2.

External Surveys

While the above methods provided a wealth of insight into project methodologies, they were distinctly internal. An important additional step was to gain access to external sources of project experience. To provide focus and maximize significance, a target group was identified for the external industry interviews. The goal was to select an audience which was based in a manufacturing industry, and more specifically the steel industry. A group of 23 senior level engineering managers and project managers, representing 21 different companies in North America were contacted. The author personally met with 17 of these individuals to explain the objectives of my research and the methods to be used in gathering the required information. Extensive effort went into an appropriate survey vehicle, and in communicating the purpose and format of the survey to the targeted audience. The survey included both "Structured" questions to obtain quantitative responses to questions along some very specific dimensions, and "Open-ended" questions to permit more latitude in describing general trends. Care was taken to ensure that the respondents clearly understood the format of the questions being asked, and were comfortable disclosing complete and candid responses. After receiving the written responses to the survey, the author followed-up with telephone conversations to further probe areas of interest. It should be noted that the projects which were the subject of these external surveys, were all large technically complex multi-year projects which averaged $70 million in size.

Additional External Interviews

Since the interaction between owner companies and their engineering suppliers was identified as an extremely critical issue in projects, contact was made to senior personnel managing large engineering and construction firms. Key project management and engineering management personnel at each company were interviewed. The objectives of these interviews were to better understand the interface between owner/engineering supplier and new trends in project management such as partnering and minimal engineering. The results of these interviews were more of a qualitative nature.

Data Analysis Methodology

The combination of personal findings, expanded Timken project experience, relevant literature, steel industry interviews, and discussions with major engineering and construction firms provided a comprehensive amount of information. The results from the expanded Timken project retrospectives, and interviews with large external engineering and construction companies were summarized and compared to the proposed CSF framework in a "qualitative" fashion. The more structured written external surveys were designed to permit more rigorous statistical testing of the hypothesized CSF framework. The methodology used to statistically analyze this data will be described in the next section.

Statistical Analysis Methodology

⇒ Survey questions were formulated to test the degree to which certain factors were present in successful verses unsuccessful projects.

⇒ By observing the consistent presence or absence of these factors in successful or unsuccessful factors, one can draw conclusions regarding their relative importance.

⇒ The data from successful projects were separated from the data from unsuccessful projects.

⇒ The identity of the respondents were maintained to be able to compare responses within the same company, and from company to company.

⇒ The data was plotted in vertical bar charts to enable visualization of the trends.

⇒ Several different statistical analysis methods were used, however they were all aimed at the same point, i.e., to determine whether for any given critical factor being examined, the data from the successful projects and those data from the unsuccessful projects are from the same population. To conduct this analysis, the author used a normal deviate test for the difference of two sample means.[2] Several statistical methods were compared, however given the relatively small sample size and paired data configuration, the paired, single and double tail T-tests shown in italics were selected as the best method for data analysis in this case;

1. Student T-test (Homoscedastic - Two tail: For comparing data sets whose variance is equal, but are randomly arranged)

2. *Student T-test (Paired - Two tail: For comparing data sets whose variance is equal, but additionally are maintained in paired responses from the survey companies. This technique allowed the variation which occurs from company to company, or respondent to respondent to be blocked out. This permitted a stronger correlation with the actual success verses failure criterion.*

3. Student T-test (Homoscedastic - Single tail: Same as above only that this method was applied where the author had strong indication when designing the survey, of the direction which one sample mean would be shifted from the other sample mean. In this case, testing only a single tail is permitted and will yield improved results.)

4. *Student T-test (Paired - Single tail: This method was applied wherever certain criteria were met, since it would provide the strongest statistical significance in the analysis. The two criteria were that the data must be maintained in pairs as indicated earlier, and that the author had strong indication of the direction of shifts in the successful verses unsuccessful population means.*

In each critical factor examined using a T-test, a Null Hypothesis was formulated and a probability of that hypothesis occurring was used as a basis for rejection or acceptance. In each case, a Null hypothesis was formulated stating that the mean values for the successful and unsuccessful project data were equal. The question being addressed was whether the data (i.e., the two observed sample means, X-bar and Y-bar) were consistent with the hypothesis that the factor existed to the same degree in both successful and unsuccessful projects. A probability was then calculated using the appropriate T-test that any difference in the observed sample means could be explained through random occurrence. The factors were then sorted, starting with those factors having the highest probability to the lowest probability of having two distinct populations, one for successful and one for unsuccessful projects

It should be noted that this T-test technique uses statistical tables based on the normal distribution. Examining the parent distribution of this data by viewing the charts created or by calculating skewness, reveals a degree of non-symmetry. It is important to discuss the appropriateness of using an analysis method inherently based on normal distributions. Box, Hunter, and Hunter address this issue stating that " when using random sampling, irrespective of the nature of the parent distribution or of the number of observations n, the mean of the distribution of y-bar and *n* and the variance of this distribution is sigma square/*n,* which are the same values found for a normal parent.

When the parent distribution is not normal, the distribution of y-bar will not be exactly normal, however as n is increased the distribution will tend to normality."[3] Thus with moderate non-normality the distribution of y-bar will be approximately the same as had the component observations been normally distributed. Procedures that rely directly on the distribution of y-bar are thus robust or insensitive to non-normality. For this analysis, it is therefore justified to apply the normal deviate comparison of two means using the students T-test.

References - Chapter 3

[1] Flanagan, J.C., "The Critical Incident Technique," American Institute of Research, University of Pittsburgh, July 1954

[2] Meyer, S.L., "Data Analysis for Scientists and Engineers," John Wiley & Sons, 1975 pp. 235-237

[3] Box, G.E., Hunter, W.G., and Hunter, J. S., "Statistics for Experimenters," John Wiley & Sons, 1978, pp. 89, 90

Chapter 4

Results - Internal Retrospectives

As described in Chapter 3, "retrospective" analyses were conducted with former project teams at The Timken Company. Four major projects, recently completed and ranging in cost from $40 million to $450 million each, were analyzed using this technique. The projects included the design and construction of state-of-the-art tapered roller bearing and alloy steelmaking facilities. Each project included extensive marketing, technical, organizational, and business challenges and opportunities. The retrospectives were the result of four separate informal brainstorming meetings, attended by key members of the four respective project teams. The following outline was used during the meetings to prompt and guide the discussions;

Discussion Points

- ✓ Strategic Development of Project (how and why did this become a project)
- ✓ Objective and Goals of Project
- ✓ Cost of Project (approximate)
- ✓ General Timeline
- ✓ Major Phases of Project
- ✓ Major Decision Points (decision making and conflict resolution techniques)
- ✓ Risk Management
- ✓ Project Control Techniques (Scope, Budget, Schedule)
- ✓ Project Team Structure
- ✓ External Resources (Consultants, Engineers, Project Managers, Suppliers)
- ✓ Success Factors (Things which contributed to success)
- ✓ Lessons Learned (Things you would recommend changing next time)

Results

Comments resulting from these four retrospectives were consolidated and listed using the 22 categories in the CSF framework introduced in Chapter 2. Since these comments were volunteered by the project teams as items of importance, their presence serves to support the issues included in the CSF framework.

1. Strategic Development Leading up to Project Formation
2. Benchmarking
3. Project Definition, Planning, Goal Definition
4. Project Team Structure
5. Work Breakdown Structure
6. Contract Structure
7. Project Manager Skills
8. Project Team Selection
9. Vision
10. Team Building and Alignment
11. Commitment to Project Goals
12. Project Management Methods
13. Risk Analysis and Management
14. Specifications and Standards
15. Engineering Expertise
16. Supplier Qualifications
17. Training of End Users
18. Senior Management Support for Project
19. Communications
20. Stakeholder Involvement (Customers, Investors, End-users)
21. Empowerment of Project Team
22. Risk Taking (Stretch)

Detailed Comments From Four Timken Project Retrospectives. (Randomly Arranged)

1. Strategic Development Leading up to Project Formation

- Significant Market/Business Analysis Conducted
- Extensive Market Research using outside consultants
- Market Segmentation Analysis
- Significant Time Invested in Feasibility /Pre-engineering
- Nearly 2 years of up front planning prior to launch helped implementation phase run smoothly.
- Excessive time was spent on planning phase, while competitors implemented technology first.

2. Benchmarking

- Purchased and evaluated steel from competitors around the world.
- Conducted world-wide benchmarking of technologies, product, organizations.
- Needed to respond more to organizational benchmarking data.
- Needed to benchmark running a small business which was foreign to Timken.
- Benchmarking was an excellent way to check reality.

3. Project Definition, Planning, Goal Definition

- Up-front planning
- Open communication during up-front planning phase.
- Experienced people were used for up-front project definition phase.
- Early awareness of EPA, Osha and Federal Regulations.
- Clearly Defined Goals were established which helped keep project on track.

4. Project Team Structure

- Full-time project team was essential to success
- Full-time project team located off-site was important to greenfield project.
- People were assigned to the project and then removed too quickly, leading to schedule slippage and re-training expenses.
- Completion of project assignments should be when milestones are completed, not calendar time.
- Second phase of project suffered due to part-time staffing.

5. Work Breakdown Structure

- Use of a pre-definition phase prior to implementation increased confidence.

6. Contract Structure

- "Cost-reimbursable" contract for Systems work led to cost over-runs.
- Needed "fixed-price" contract for automation just like other parts of project.
- Functional specifications could be developed using a Time and Material Contract
- Used a "bi-lateral purchase document" detailing "as-purchased" specifications.
- Purchased equipment and services in a down market, which saved money.
- All installation contracts were bid fixed price.
- Used detailed, measurable performance guarantees with meaningful penalties.
- Project had a strong and effective "Purchasing" team.
- Subcontractor management was difficult the way contracts were written.
- Needed better definition of roles between suppliers and sub-suppliers.

7. Project Manager Skills

- Project Manager viewed facility as the eventual owner or plant manager.
- There was excessive turnover in Project Leaders which jeopardized project vision.
- Project Manager had broad skills.
- Project Manager maintained a business perspective throughout project.
- Project Manager was effective at leadership and delegation.

8. Project Team Selection

- Selected a highly qualified team.
- Other programs stole time away from project team.
- Need to be decisive and swift in replacing poor performers on the team.
- Selected and insisted on the "best" people for internal and external project teams.
- Fully dedicated project team was essential.
- Well balanced team with multi-disciplines.
- Purchasing was part of project team.
- Team members were made readily available to the project.
- Team work environment was excellent with an atmosphere of trust and openness.

9. Vision

- The vision for the plant accounted for the latest thinking in terms of manufacturing excellence.
- Vision had a good balance between Technical and Business Objectives
- Vision drove continuous and rigorous attention to total business focus. (never let project slip into a "technology or operating project")
- Project Vision challenged corporate paradigms and had us think "outside the box."
- Did a good job of defining decision criteria for systems development, e.g. safety, schedule, corporate standards, budget, user needs, etc.
- Needed clearer vision for automation scheme to ensure effective and efficient systems are installed.
- Vision was developed at the top, was not fully understood at lower levels of organization, and therefore lacked broad support.
- Initial Vision and project scope was much larger initially, which led to a lot of expensive preparatory work which was never used.
- Time spent on vision and conceptual work was excessive and rushed implementation.
- Some items debated in detail at the concept stage never ultimately materialized.
- Project Vision needed revision due to the length of time it took project to move from concept to startup. (or project cycle needed compressed.)

10. Team Building and Alignment

- Locating team together created an esprit de corps and sharing of project goals.
- Conducted formal team building within team and with suppliers.

11. Commitment to Project Goals

- Realistic, fixed deadlines helped with project discipline.
- High set of expectations to meet project schedules and goals.
- Never compromised functionality/quality to save money.
- Maintained an absolute schedule commitment.
- No compromises to process or product quality were permitted.
- Customer promise for delivery imposed an absolute schedule deadline which turned out to be a real plus to keep project on track.

12. Project Management Methods

- Used strong project management methods including a formal change control procedure.
- Maintained rigorous project discipline and schedule management.
- Used outside company with excellent PM experience and methodologies.
- Construction outage planning was done very well and avoided surprises or delays.

13. Risk Analysis and Management

- Conducted process trials ahead of startup. (e.g. electromagnetic stirring, casting speed, sequence casting, refining practices.
- Developed mathematical and physical models as prototypes of actual process.
- Developed discrete event computer simulations early in the design stage to study equipment layout, material flow, and productivity.
- Early investigations permitted quality assessment before customer shipments.
- Pre-produced critical customer orders prior to equipment outage.
- Pre-tested critical sub-systems prior to actual facility start-up.
- Used philosophy of "Leading Edge, but Proven" technology for project.
- Pre-testing of all automation sub-systems with later "integration" testing.
- Built contingency planning matrix for automation systems, defining; a.) Must have, b.) Should have, and c.) Nice to have, functionality.

14. Specifications and Standards

- Enforced adherence to standards.
- First in industry to use functional specifications for all automation systems.
- Applied "first engineering submittals" concept to ensure adherence to functional specifications.
- Developed an approved equipment list for used by suppliers, which helped with training and maintenance of equipment.

15. Engineering Expertise

- Develop strong and experienced process engineers which helped with start-up.
- Internal engineering expertise helped design quality and equipment startup.

16. Supplier Qualifications

- The quality and location(accessibility) of suppliers was important.
- Selected suppliers capable of delivering "leading edge" but proven technology.
- Used consultants for specialized advanced process issues.
- Use of high quality outside engineering and construction company.
- Checked references of suppliers, including financial profiles.
- Outside project management company had excellent purchasing department.
- Outside project management company was costly for portions of project.
- Quality of start-up personnel assigned by suppliers was crucial.
- Used spot audits (progress checks) at suppliers to ensure quality and delivery.

17. Training of End Users

- The selection, training, and development of operators was essential.
- Sent operators to Japan to train on new process and view Japanese work culture.
- Utilized most experienced operators at start-up.
- Need to properly train all eventual users of automation systems prior to installation.
- Sent dedicated process control engineers to software suppliers to intimately learn system prior to installation.
- Underestimated the resources required to train people, and to later cross train them.
- Cross trained associates to create a highly flexible work force. Worked well but took a lot of time which was not planned for.
- Training on preventative maintenance procedures was short-changed.
- Highly qualified associates were selected and received extensive training prior to startup.

18. Senior Management Support for Project

- Executive Sponsor
- Project had a very senior management champion.
- Strong corporate priority was assigned to project.
- Project was the company's #1 priority at the time, which helped secure resources.
- Project received top management attention (Undivided and consistent)
- Project did not fit well with the head of the business's view, lacked support.

19. Communications

- Communications played an important role on project.
- Regular weekly meetings were held with key project personnel.
- Regular meetings with key suppliers helped anticipate problems.

20. Stakeholder Involvement (Customers, Investors, End-users)

- Integration of project and involvement of existing organizations was crucial since this was a brownfield (retro-fit) project.
- The ultimate operators designed the process and plant arrangement.
- Project lacked process metallurgy's direct involvement which slowed startup progress.
- Involved too many people too early, in organizational redesign. Needed to work first with the management team.
- Did not gain the full buy-in on automation systems, and users resisted some new systems after start-up.
- Have not achieved full buy-in from maintenance associates as compared to operating associates.
- Used maintenance associates to help select equipment which they could realistically be able to maintain.
- Project involved maintenance associates to pre-establish PM procedures.
- Key operating managers lived with project from beginning to startup.
- Brought maintenance/operating people on board early to help develop PM's, and install and debug new equipment.
- Involved people to achieve "Buy-In" and knowledge.
- Viewed project as a means to an "Operating Facility", not as an end.
- Maintained a close relationship with customers throughout life of project.
- Communicated with customers early and often during and after plant startup.
- Marketing was only involved part-time during the concept phase of the project, and some valuable customer-driven input was missed. .

21. Empowerment of Project Team

- The authority of the project team was recognized and important when dealing with outside suppliers.
- Project team had the authority to juggle individual elements of the budget in to achieve the promised functionality within the overall project budget.
- Project team was fully empowered and left alone to make own decisions.
- Executive sponsor compromised the autonomy of the team on a few decisions, but overall provided good support for the team.

22. Risk Taking (Stretch)

- More formal risk assessment should have been used to ensure the project stretched the performance envelope sufficiently.
- Decision to use "Leading Edge of Proven Technology" may have led to excessive risk avoidance.
- There was no good objective measure to ensure that the correct balance of risk/reward was achieved.
- The project vision was slightly idealistic, but it did provide a tremendous amount of stretch.

Chapter 5

Results - External Retrospectives

As described earlier in the methodology overview, senior level engineering managers and project managers were surveyed on the topic of project success factors. The author contacted 23 senior level engineering managers and project managers, representing 21 different companies in the North American Steel Industry. "In-person" contacts were made with 17 of these managers to discuss this topic of project management. Detailed surveys on 18 recent strategic projects were completed as a result of these contacts. Each of these projects fit the author's definition of "strategic" projects and averaged $70 million in cost. It should also be noted that these projects were all completed in the recent past. The average year of completion for the successful projects was 1993, and for the unsuccessful projects was 1991

Objectives of the study:

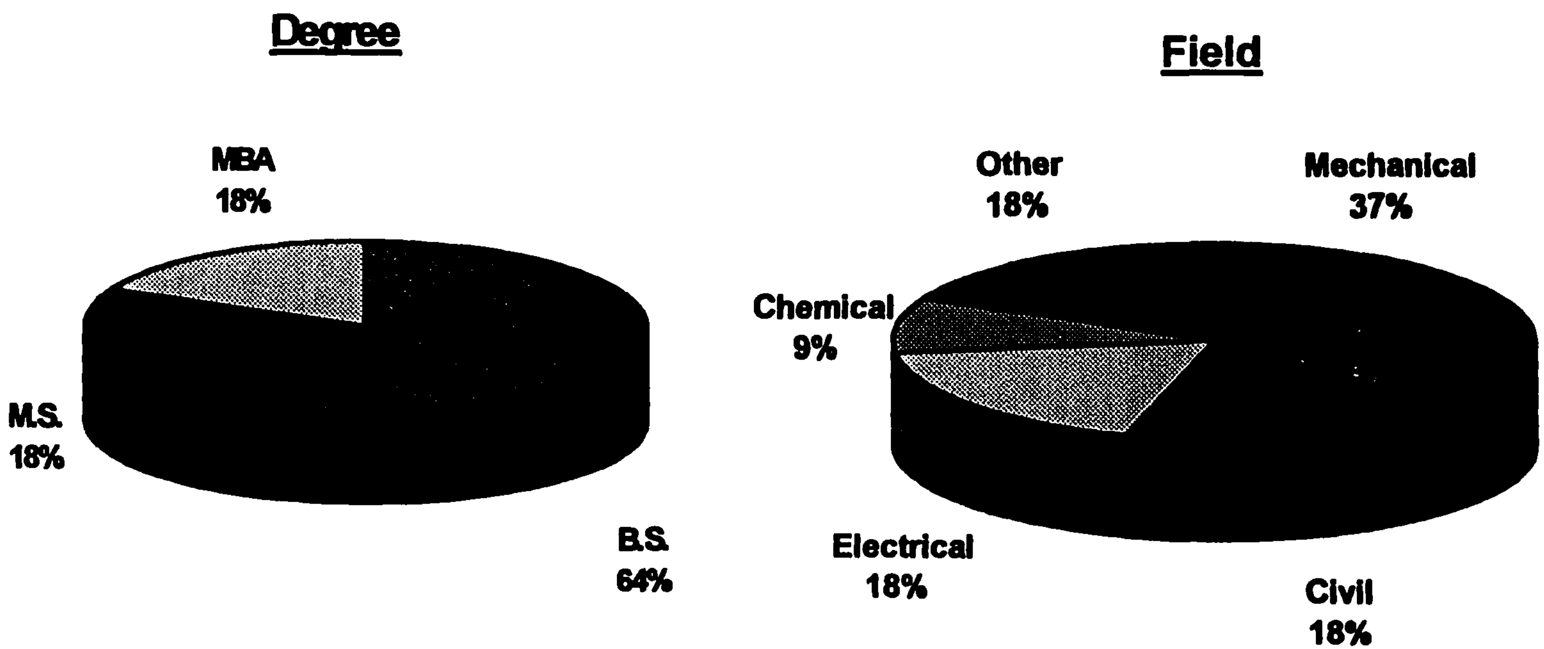
The specific objectives of these surveys were to gain new insight into trends in engineering and project management, the implications of these trends to companies and individuals working as engineers and project managers, and factors critical to success of large strategic projects.

Background Of Those Responding To Survey

The individuals responding to this survey had extensive engineering education and project management experience in the steel industry. As can be seen in Figure 5.1, 37% had a degree in mechanical engineering, 18% in civil engineering, 18% in electrical engineering, and 9% in chemical engineering. Thirty-six percent had advanced degrees in either science or business. All had significant project management experience as indicated in Figure 5.2. The average experience in project engineering was an impressive 28.7 years. Figure 5.3 shows the individual experience in the form of project costs. The individual project experience of 90% of those responding was in excess of $200 million, while 45% exceeded $500 million during the course of their career.

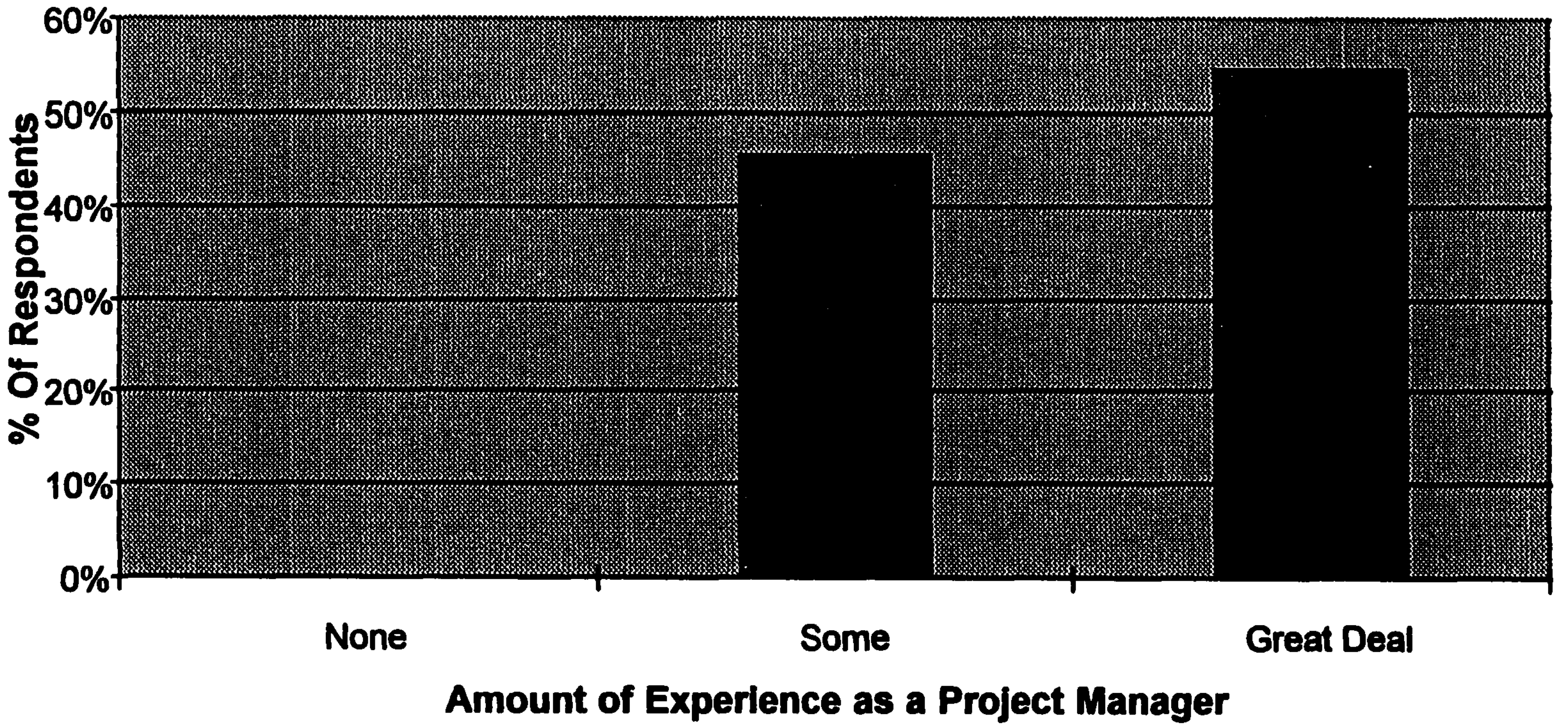
Educational Background of Project Management Survey Respondents

Figure 5.1



Project Management Experience of Survey Respondents

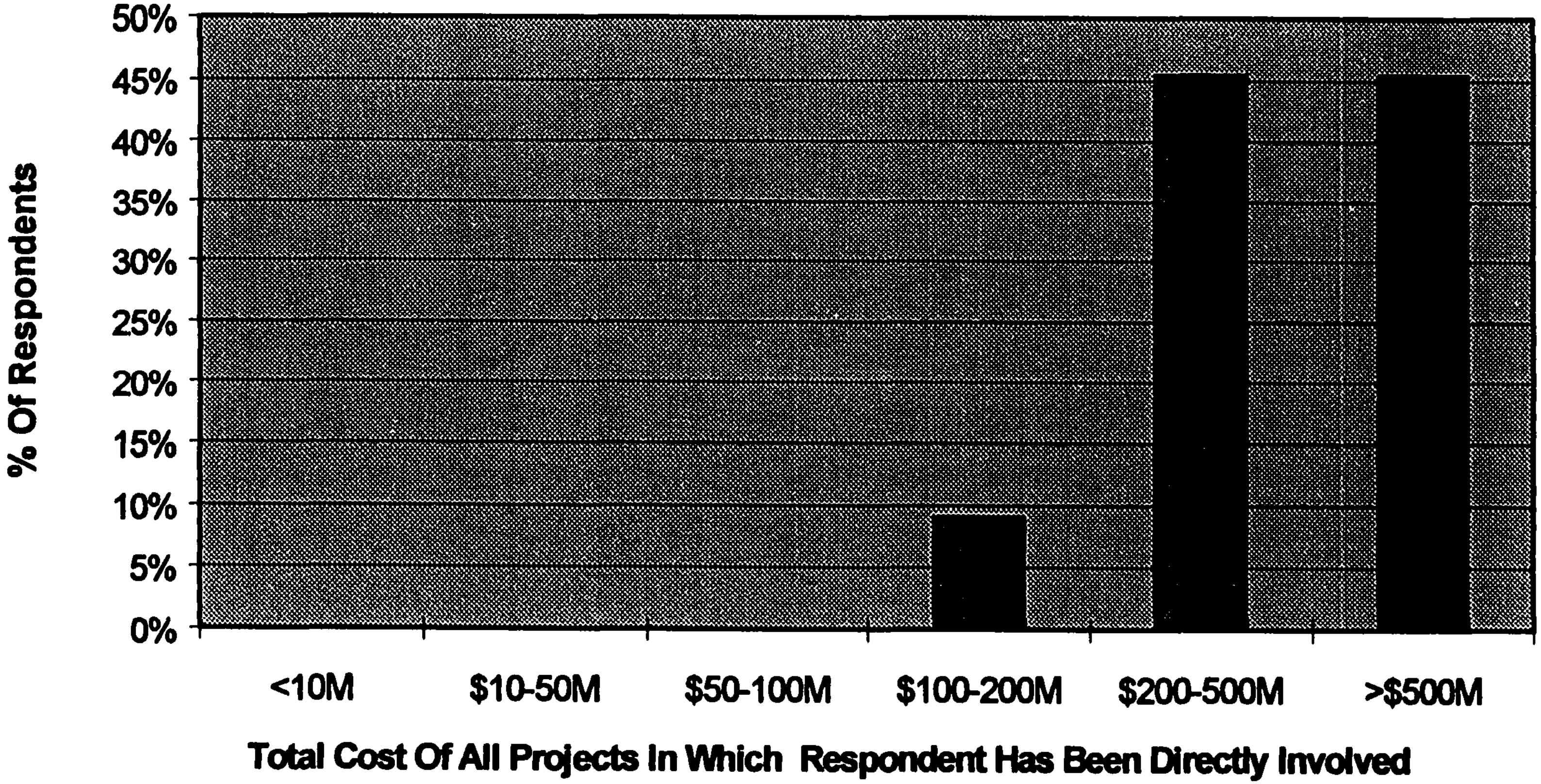
Figure 5.2



Note: Average project engineering experience of respondents was 28.7 years.

Total Project Experience of Survey Respondents

Figure 5.3



Survey Format

Extensive effort went into developing an appropriate survey vehicle, and in communicating the purpose and format of the survey to the targeted audience. The survey was a written format, including "structured" questions to obtain quantitative responses to questions along some very specific dimensions, and "open-ended" questions to permit more latitude in describing general trends. Care was taken to ensure that those surveyed clearly understood the format of the questions being asked, and were comfortable disclosing complete and candid responses. Assurance was given to the individuals being surveyed that any information provided would be treated with the strictest confidence. Individual names would not be disclosed and responses would be discussed in aggregate form only. The information would not be used for any reason other than for the stated academic purposes. The following is an introductory set of instructions which were provided with the surveys.

Critical Factors Influencing Project Success - Assessment Exercise

To complete this portion of the survey, you will need to select two projects for analysis, using the following criteria;

A. The projects should be "strategic capital" projects, which to help clarify I will define as being *either*;

⇒ Large in terms of financial commitment (perhaps greater than $10-20 million).
⇒ Containing a significant amount of challenge or risk, (e.g., technical, commercial, organizational).
⇒ Requiring Senior Management or Board Level Approval.
⇒ Spanning several years from initial concept and business analysis, to completion and startup.

B. One of the selected projects should have been "Highly Successful" as defined by you. The second project should also have been carried through to completion, but having failed to meet significant performance, scope, budget, or schedule expectations, was considered "Unsuccessful" (or much less successful). The successful project will be referred to as Project "A", while the unsuccessful project will be called Project "C".

C. It is important for you to have direct knowledge of the projects. You need not have been directly on the teams managing the projects, but you must have a good understanding of the goals of the projects, the methods used to manage them, and their general outcomes. While your knowledge of the projects should be direct, you do not need to have precise details.

D. You need to be willing to discuss certain aspects of the projects in order to make this analysis complete and valid, (e.g. general objectives, sources of risk, project organization, general results). This would not of course need to include any confidential or competitive information. Any information provided will be treated with the strictest confidence. Individual names will not be disclosed and information will be discussed in aggregate form only. The information will not be used for any reason other than for the stated academic purposes.

Project Management Survey Responses

Open-ended Questions

Responses were first requested to the following open ended questions;

- Objectives of "Highly Successful" Projects
- Objectives of "Unsuccessful" Projects
- Reasons Cited for calling Projects Highly Successful
- Reasons Cited for calling Projects Unsuccessful
- Critical Aspects Which Made Projects Successful
- Critical Aspects Which Made Projects Unsuccessful
- Trends Making Project Development and Project Management Easier
- Trends Making Project Development and Project Management More Difficult

These qualitative individual responses were then categorized into common themes or "sub-points", and are presented in pages 56 through 70, as paraphrased bullet points.

Project Management Survey Responses

Objectives of "A" Projects - Highly Successful Projects

Quality

- Meet quality requirements of targeted market
- Improve heating characteristics of reheat furnace
- Improve product quality
- Improve annealing capabilities

Productivity Improvements

- Produce product at prices competitive with the low cost producer
- Install a new caster to replace ingot production.
- Lower manufacturing costs
- Improve yield and labor productivity
- Replace obsolete rolling facilities with an automated forging line

Marketing

- Meet Market demand for 100% Continuously Cast Steel
- Protect current shipment levels and contribution to fixed costs.
- Increase profit margins

Project Execution

- No interruptions to existing operations or to our customers
- No lost time accidents during construction
- Complete project for a fixed budget and by a fixed schedule

Social

- Develop improved work culture

Project Management Survey Responses

Objectives of "C" Projects - Unsuccessful Projects

Quality

- Improve product quality
- Develop capability to supply defect-free product to customer
- Install facility to verify product quality to ensure defect free product
- Provide quality feedback upstream for continuous process improvement
- Ability to meet more restrictive quality levels

Productivity Improvements

- Reduce operating costs
- Replace two old operations with one modern line
- Improve labor productivity
- Improve equipment reliability
- Upgrade process with modernized controls
- Increase capacity and productivity
- Implement a new process technology with promised lower costs
- Construct a rolling mill to directly roll continuous cast blooms

Marketing

- Retain market share in high margin products
- Satisfy anticipate new market demands

Social

- Improve work culture with an empowered workforce

Project Management Survey Responses

Reasons Cited For Calling Projects Highly Successful

Quality (7 Citations)

- Quality and Productivity objectives were met
- Customer requirements were fulfilled with no complaints
- All quality goals were met
- Have demonstrated product quality far beyond design goal
- Achieved all anticipated quality improvements
- Provided salable product on first attempt
- Project accomplished all process and manufacturing goals

Operational (11 Citations)

- Startup progressed ahead of projected production curve
- Major production milestones were met ahead of schedule
- All major automation systems worked first time at startup
- Built good relationships with operators and maintainers
- Met full production on second day of operation
- Minimal interference with operations during construction and startup
- No lost time accidents
- No disruptions to operations or customers
- No production outage other than normal downtime.
- Shipments were fully maintained throughout construction and startup
- Shutdown was kept to 30 days

Project Management Survey Responses

Reasons Cited For Calling Projects Highly Successful (cont'd)

Marketing (2 Citations)

- Created new market niche
- Gained a significant competitive advantage in the market

Schedule (7 Citations)

- Record short project time to install this type of caster
- Beat installation date by 3 months
- Project Schedule was met
- Project was a fast track project and was completed on time
- Start up was ahead of schedule
- Schedule was met
- Project started up ahead of schedule

Project Budget (8 Citations)

- Project completed on budget
- Budget was met
- Project met and exceeded ROI
- New contract concept kept cost below budget
- Cost was under budget
- Exceeded cost reduction targets
- Met budget within 2%
- Project completed within budget

Project Management Survey Responses

Reasons Cited For Calling Projects Unsuccessful

Quality (6 Citations)

- Failed to meet objectives after 3 years of operation
- Performance guarantees were not 100% achieved
- Quality data is not used to improve upstream operations as planned
- Never met performance objectives
- Primary process objective never achieved due to metallurgical problems
- Equipment supplier failed to deliver first time quality design

Operational (7 Citations)

- Full capacity was never achieved
- Automation system was too costly and never truly utilized as planned
- Workforce is not demonstrating commitment to self-manage
- Proper maintenance of new equipment not occurring and reliability is poor
- Equipment design flaws discovered during startup and operation
- Excessive operating costs made new process impractical
- New work system for operators/maintainers has not achieved goals

Project Management Survey Responses

Reasons Cited For Calling Projects Unsuccessful (cont'd)

Marketing (1 Citation)

- While the facility was successful built, it's strategic intent was fatally flawed

Schedule (4 Citations)

- Experienced prolonged startup problems
- Startup missed by 5 months
- Startup was horrendous
- Outage took 30% longer than planned

Project Budget (4 Citations)

- Exceed budget by 30%
- Overran budget by 20%
- Ran well over budget
- Project scope and design was not controlled

Project Management Survey Responses

Critical Aspects Which Made Projects Successful

Planning

- Detailed planning was used
- Detailed planning prior to executing project
- Excellent detailed planning
- Excellent Vision on part of originators of project
- Good project development, i.e. strategic planning and equipment selection
- Preliminary engrg and detailed budget developed prior to appropriations
- Minimal scope changes occurred.

Goal Definition

- Responsible parties had clear understanding of goals
- Firm, clearly defined project goals and schedule
- Project goals were firm and helped focus the project team
- Having organized schedule identifying all objectives to be accomplished

Project Staffing

- Appropriate resources were assigned
- Excellent communications, cooperation, and training of owner employees
- Cooperative Team environment on project
- Full time cross functional project team
- Design and construction managed by one project team
- Internal project team managed facility design engrg in prep. for equipment

Project Management Survey Responses

Critical Aspects Which Made Projects Successful (cont'd)

Project Management Techniques

- Good basic project management techniques were employed
- Monitoring mechanisms were in place
- Corrective actions were taken immediately when a deviation occurred
- Extended time to review quotations to clarify technical/commercial defn
- Detailed critical path schedule was maintained throughout project life

Contract Structure

- Contract structure with bonus/penalty which led to shared goals
- Favorable project labor agreement with AFL/CIO
- Partnering arrangement with all suppliers
- Equipment supply, erection, & startup with single source turn-key

Employee Involvement

- Use of cooperative in-house engineering on project
- Excellent cooperation with Operations and Maintenance Personnel
- Strong ownership of workforce in plant due to participation
- Good teamwork between engrg, operations, internal crafts, and supplier
- Complete integration with operators and maintenance personnel
- Involvement of operators and maintainers from the very start of project
- Total involvement of all operating and maintenance personnel
- Good involvement of maintenance and operating personnel during project.
- Direct involvement of maintenance and operating supervisors.
- Willingness by operating/maintenance to accept change and take ownership

Project Management Survey Responses

Critical Aspects Which Made Projects Successful (cont'd)

Project Manager

- Committed project manager who was later assigned to manage operation
- Project manager who ultimately ran facility was fully empowered
- One person clearly in charge as Project Manager
- Outstanding construction manager with a great deal of experience

Executive Sponsor

- Total support of senior executives to use partnering concept
- Gutsy decision, willingness to take risk in proceeding with project
- High level executive sponsor who kept awareness of soft project issue
- Supportive senior management executive sponsor.

Quality of Suppliers

- Excellent suppliers used for equipment and construction
- High quality engineering and project management.
- Proper design and selection of equipment
- Benchmarking and selection of world leading technology
- Excellent technical support from suppliers

Pre-testing of Systems

- Early development and testing of design prior to operational startup
- Installation and checkout of computer system prior to equipment startup
- Commissioning and startup after all systems were complete

Project Management Survey Responses

Critical Aspects Which Made Projects Unsuccessful

Planning And Development

- Project was inadequately developed and planned
- Project was developed by a committee, and was a victim of "group think"
- Facility capacity poorly planned and did not balance upstream processes
- Poor job of strategic planning for the project.
- Project planned by separate group and handed off to implementation team
- Functionality not fully thought through until mid-way through project.
- Facility material flow was never simulated or properly forecast
- Executive sponsor didn't believe in strategic planning prior to projects
- Lack of product development direction delayed customer qualifications

Project Manager

- Project manager had no experience managing a large project
- Project manager not team oriented and was combative with suppliers
- Project manager who would not work well with people
- Project manager was not empowered to make decisions
- Freestyle type of project with loose control in place
- Management didn't recognize early symptoms of problems with the project

Project Management Survey Responses

Critical Aspects Which Made Projects Unsuccessful (cont'd)

Supplier Selection

- Supplier did not have the technical expertise needed for the project
- Poorly selected suppliers
- Selected the wrong construction company
- Poor selection of engineering and equipment suppliers
- Engineering supplier had no experience with this type of process equipment

Contract Structure

- Use of turnkey contract resulted in loss of control over "value" decisions
- Lean owner project team, overly reliant on turnkey contractor
- Owner lacked experience and didn't hire needed technical assistance
- Turnkey supplier dominated process technology supplier with no recourse
- Outside engineering firm was used to manage the project
- Three tiered contract resulted in no direct control over equipment designer
- Construction was performed as Time & Matl with a % markup
- Only budgetary estimates of construction costs were made in advance

Construction

- Poor labor climate led to poor construction quality and productivity
- Powerful labor unions insisted on costly and inefficient union workers
- Construction started before blueprints were completed
- Conflicts w/ civil & electrical construction created delays in electrical work

Project Management Survey Responses

Critical Aspects Which Made Projects Unsuccessful (cont'd)

Technology Obsession

- Inadequate scale-up testing prior to attempting new technology
- Enamored with the new technology being installed
- Constant innovation occurring during and after installation

Automation

- Poor system integration design led to cost overruns
- System design problems extended beyond startup & delayed production
- Poor contract led to multiple program languages causing startup delays

Employee Involvement

- Operators/Maintainers assigned too late, after key design decisions made
- Development team didn't include key operating and maintenance personnel
- Inadequate spec review by Oper. & Maint. leads to late design freeze
- No committed maintenance personnel stayed on project team full-time
- Key project team operations member left company during project
- Operations had hidden agenda different from project strategic intent
- Very little participation by operators or maintenance
- Operators got involved too late in project
- Scheduling personnel critical to operational success not involved
- Selection criteria for oper't'g and maintenance personnel not strict enough

Project Management Survey Responses

Trends Cited Making Project Development and Project Management Easier

Software

- PM Software(e.g.Primavera)/Document Control Software(e.g. Execution)
- Better software for project management and control
- PC based tools (e.g. database, spreadsheet, scheduling tools)

Suppliers

- Engineering companies have improve ability to control/manage big projects
- Partnering with Qualified Suppliers
- Partnering
- Team Building

Contract Structure

- Target Price Contracts
- More outside help from lawyers and financial analysts

Project Management Survey Responses

Trends Cited Making Project Development and Project Management More Difficult

Minimal Engineering

- Minimal Engineering
- Minimal construction engineering leading to more field errors and expense.
- Need to design for easier maintainability(i.e. minimal maintenance required)

Globalization of Suppliers

- Global Engineering
- Global Purchasing
- Very little technology is coming from U.S.A.
- Major equipment suppliers are located overseas.

Downsizing

- Smaller project teams with key decision-making authority
- Internal engineering staffs have been downsized or eliminated.
- Engrg companies have downsized, impacting engrg. quality/availability
- Pressure to do projects faster with fewer full time people.

Project Management Survey Responses

Trends Cited Making Project Development and Project Management More Difficult (cont'd)

Budget Pressures

- Drive to keep asset base (i.e. capital) low and still meet project objectives
- Project budgets are pressured increasingly.

Purchasing Methods

- Purchasing competitively bidding everything as a commodity.
- Competitive bidding encouraged "low-balling" with later claims for extras
- Unions forced use of union construction workers with low productivity.
- Non-turnkey approach. Owner retains most of risk and control?

Social

- Partnering/team approach can be win-win but difficult to manage
- Participative management trend makes project development cumbersome.
- Involvement of massive number of people touching project 250 to 350

Project Skills

- Need for improved strategic project planning to ensure business success
- Fast track projects using PM's inexperienced with "fast tracking" methods
- Increased use of automation has added complexity and risks to projects.
- PM ultimately responsible to operate/maintain facility (not just build it)

Structured Questions

The respondents were then asked the following questions regarding their projects;

1. Amount of Strategic Analysis Used To Develop Project
2. Degree of Scope, Budget, And Schedule Definition
3. Degree Of Goal Definition Prior To Project Approval And Launch
4. Who Established Goals and Degree of Challenge For The Project
5. Risk Management Techniques Which Were Employed On Project
6. Project Goals Which Were Considered Absolutely Fixed
7. Level Of Project Executive Sponsor
8. Project Manager Background and Skills
9. Degree of Project Manager Empowerment
10. Was Project Manager To Ultimately Manage The New Facility
11. Project Team Structure And Location
12. Level of Detail Used By Owner In Design and Purchase Specifications
13. Level Of Detail Used In Engineering Drawings
14. Source of Design and Engineering Services for the Project
15. Amount of Owner In-house Engineering Expertise
16. Level of Process Control and Automation Systems Involved in Project
17. Amount of Customer Involvement Throughout The Project
18. Project Areas Where Operating Personnel Were Involved
19. Project Areas Where Maintenance Personnel Were Involved
20. Use of Performance Incentives
21. Use of Turn-key Contracts
22. Use of Fixed Price Contracts
23. Use of Time & Materials Contracts

The responses to these questions are graphed using vertical bar charts in Figures 5.4 through 5.26 and summarized statistically in Tables 5.1 through 5.23. In each graph the results of the successful projects are shown separate from the unsuccessful projects, making a direct visual comparison possible. The statistical analyses are likewise separate for the successful and unsuccessful projects.

The Amount Of Strategic Analysis *used to develop successful projects was significantly greater than the amount used for unsuccessful projects.*
(Confidence Level: 94%)

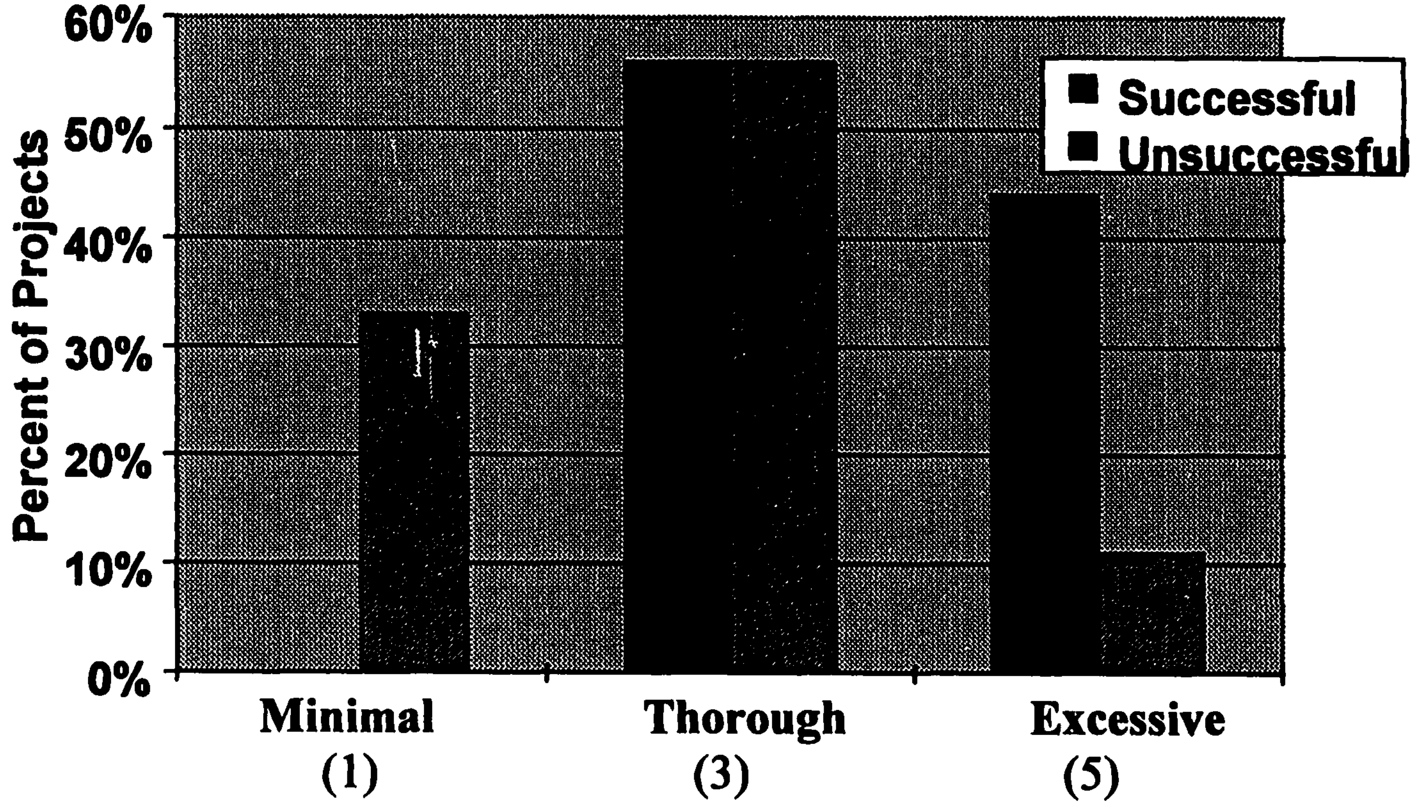


Figure 5.4

Table 5.1 - Amount of Strategic Analysis

	Observation	Successful	Unsuccessful
	1	5	1
	2	3	3
	3	3	5
	4	5	1
	5	3	3
	6	5	3
	7	3	3
	8	5	1
	9	3	3
	Total	35	23
	Mean	3.888888889	2.555555556
	Std Dev	1.054092553	1.333333333
	95% Conf	0.688660419	0.871093597
	90% Conf	0.577942678	0.731045595
	80% Conf	0.45029124	0.569577988
95% Conf	Min	3.20022847	
	Max		3.426649152
90% Conf	Min	3.20022847	
	Max		3.286601151
80% Conf	Min	3.438597648	
	Max		3.125133544

	90% Conf	0.577942678	0.731045595
90% Conf	Min	3.310946211	
	Max		3.286601151

T-test (homoscedastic):	0.031721995
T-test (paired):	0.111434288
T-test (homoscedastic, single tail):	0.015860998
T-test (paired, single tail):	0.055717144

***The Degree of Project Scope, Budget, and Schedule Definition** prior to final approval and launch was significantly higher for successful projects than for nonsuccessful projects.*

(Confidence Level: 97%)

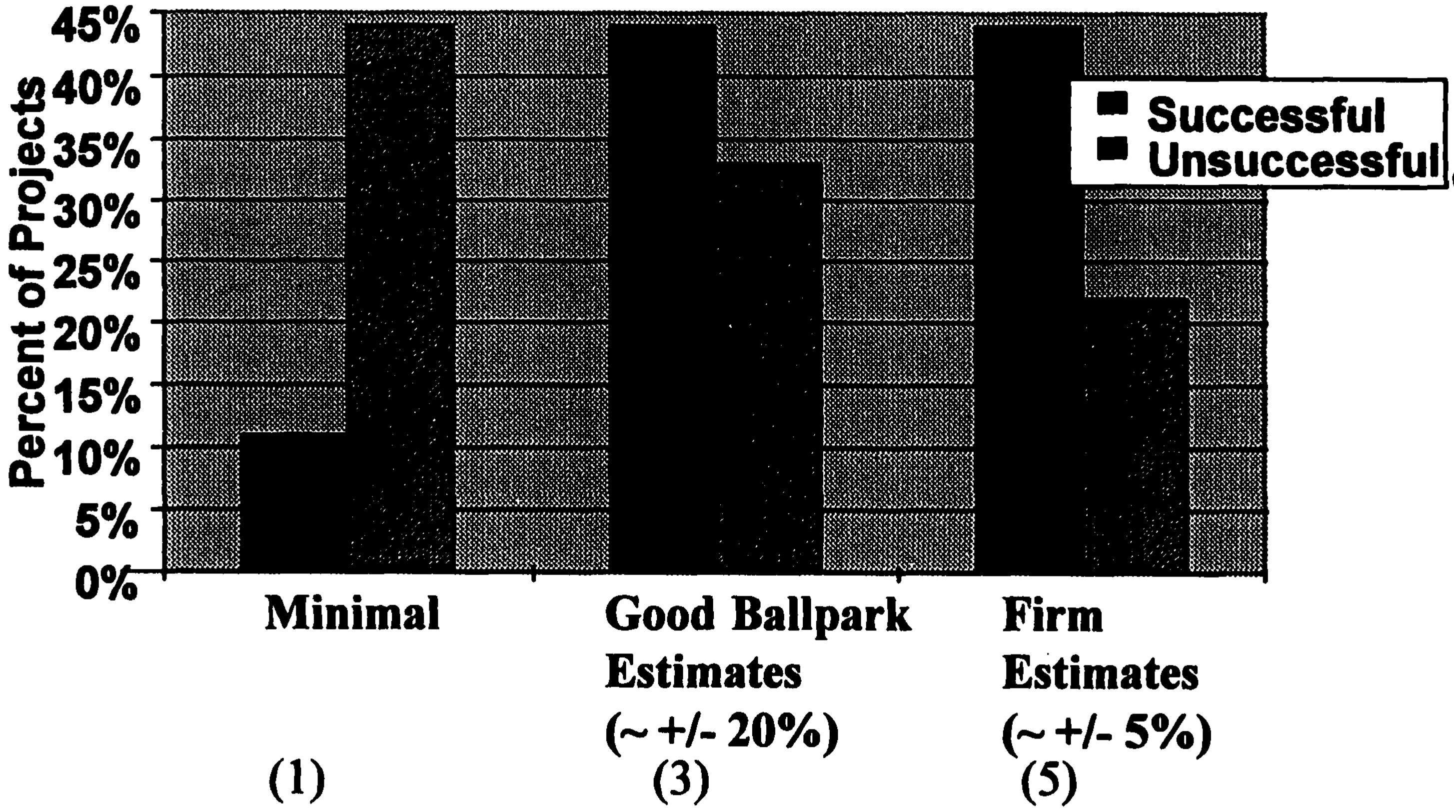


Figure 5.5

Table 5.2 - Degree of Scope,Budget,Schedule Defn.

	Observation	Successful	Unsuccessful
	1	5	5
	2	5	1
	3	3	3
	4	5	3
	5	3	1
	6	3	1
	7	1	1
	8	5	5
	9	3	3
	Total	33	23
	Mean	3.666666667	2.555555556
	Std Dev	1.414213562	1.666666667
	95% Conf	0.923934801	1.088867486
	90% Conf	0.77539138	0.913807405
	80% Conf	0.604129025	0.711972806
95% Conf	Min	2.742731866	
	Max		3.644423041
90% Conf	Min	2.891275286	
	Max		3.469362961
80% Conf	Min	3.062537642	
	Max		3.267528361

	72% Conf	0.509268146	0.6001782
72% Conf	Min	3.157398521	
	Max		3.155733756

T-test (homoscedastic):	0.146784679
T-test (paired):	0.050933249
T-test (homoscedastic, single tail):	0.073392339
T-test (paired, single tail):	0.025466625

__Projects with Clearly Defined and Measureable Goals__

prior to approval and launch were more successful than those projects having a less defined set of goals.

(Confidence Level: 99%)

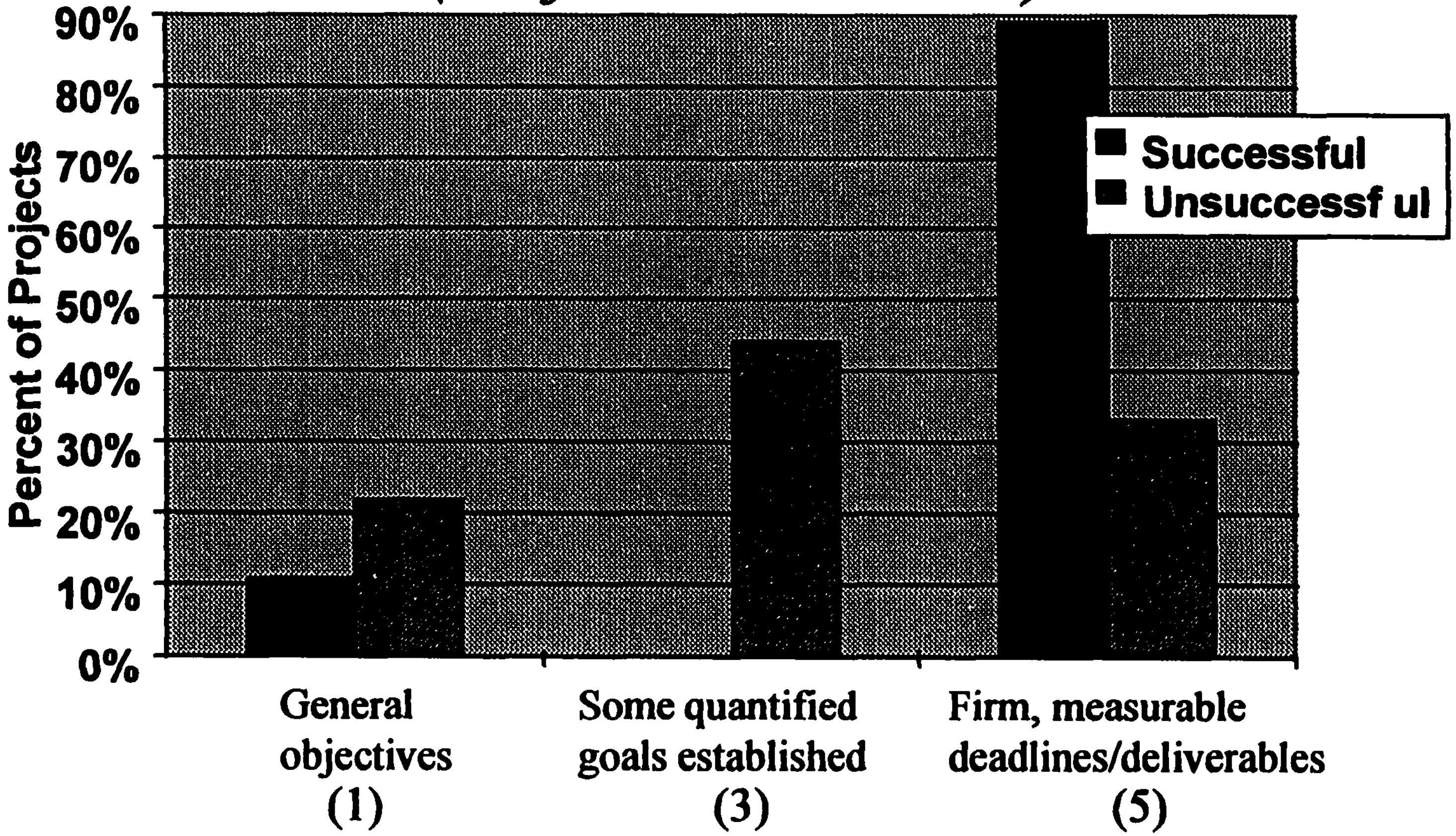


Figure 5.6

Table 5.3 - How Formal and Firm Were Upfront Goals

	Observation	Successful	Unsuccessful
	1	5	3
	2	5	5
	3	5	3
	4	5	3
	5	5	3
	6	1	1
	7	5	5
	8	5	1
	9	5	5
	Total	41	29
	Mean	4.555555556	3.222222222
	Std Dev	1.333333333	1.56347192
	95% Conf	0.871093597	1.021448091
	90% Conf	0.731045595	0.857227203
	80% Conf	0.569577988	0.667889595
95% Conf	Min	3.684461959	
	Max		4.243670313
90% Conf	Min	3.82450996	
	Max		4.079449426
80% Conf	Min	3.985977567	
	Max		3.890111817

	83% Conf	0.609868594	0.715134531
83% Conf	Min	3.945686962	
	Max		3.937356753

T-test (homoscedastic):	0.069352061
T-test (paired):	0.022203904
T-test (homoscedastic, single tail):	0.03467603
T-test (paired, single tail):	0.011101952

Who Established Project Goals and Degree of Challenge

did not correlate to project success. Goals and degree of challenge were most frequently established at senior management levels.

(Confidence Level: 31%)

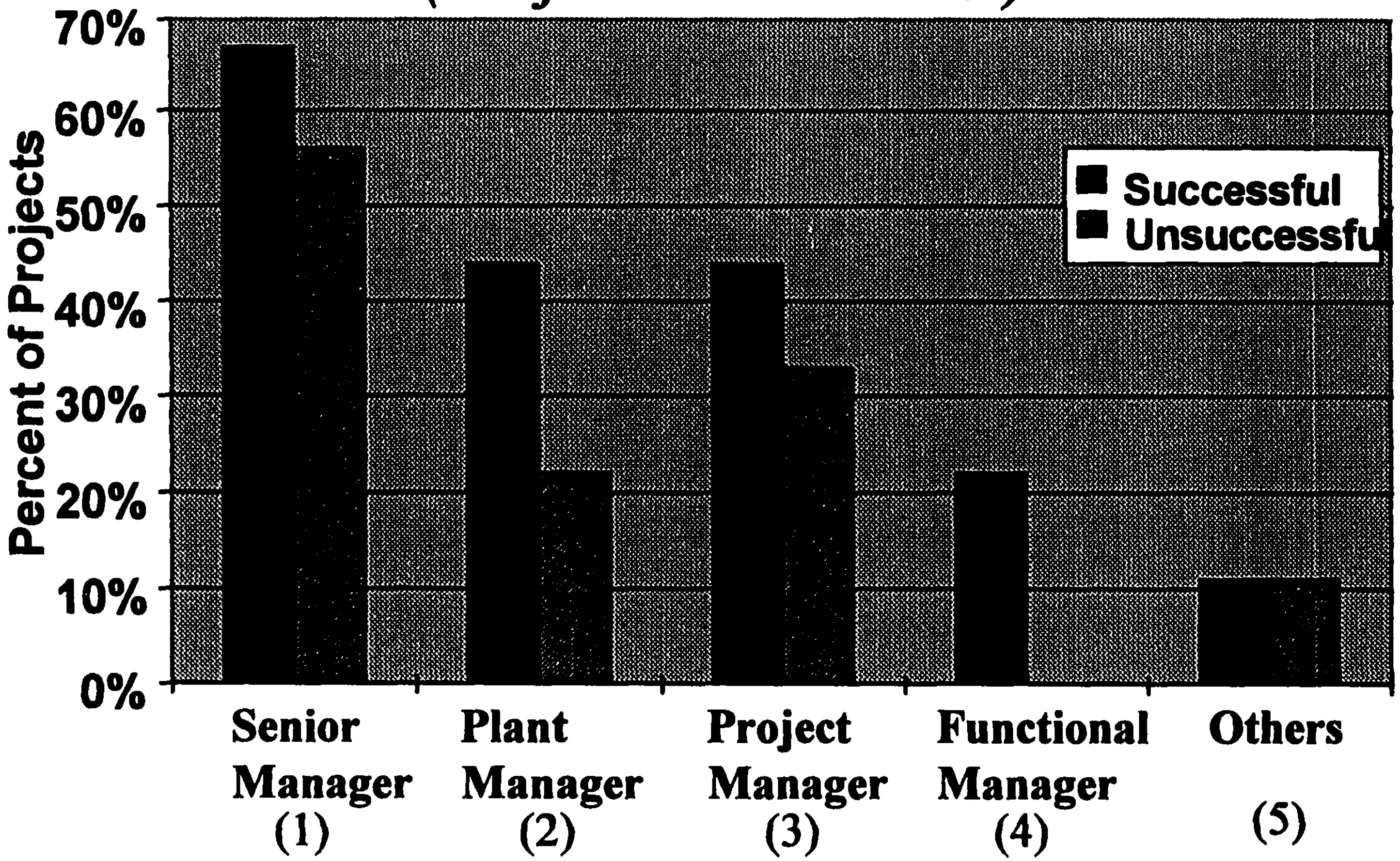


Figure 5.7

Table 5.4 - Who set the project goals and their stretch

	Observation	Successful	Unsuccessful
	1	1.00	1.00
	2	1.00	1.00
	3	2.50	3.00
	4	3.00	3.00
	5	3.00	5.00
	6	2.00	1.00
	7	1.00	1.50
	8	2.67	1.00
	9	1.50	2.50
	Total	17.67	19
	Mean	1.96	2.111111111
	Std Dev	0.861114516	1.386943081
	95% Conf	0.562583646	0.906118154
	90% Conf	0.472135598	0.760439163
	80% Conf	0.367853997	0.592479336
95% Conf	Min		1.204992957
	Max	2.53	
90% Conf	Min		1.350671948
	Max	2.44	
80% Conf	Min		1.518631775
	Max	2.33	

	15% Conf	0.054284101	0.087431992
15% Conf	Min		2.023679119
	Max	2.02	

T-test (homoscedastic):	0.788921521
T-test (paired):	0.687532808
T-test (homoscedastic, single tail):	0.394460761
T-test (paired, single tail):	0.343766404

<u>The Amount Of Risk Management Employed</u> on successful projects was higher than that employed on unsuccessful projects. (Confidence Level: 92%)

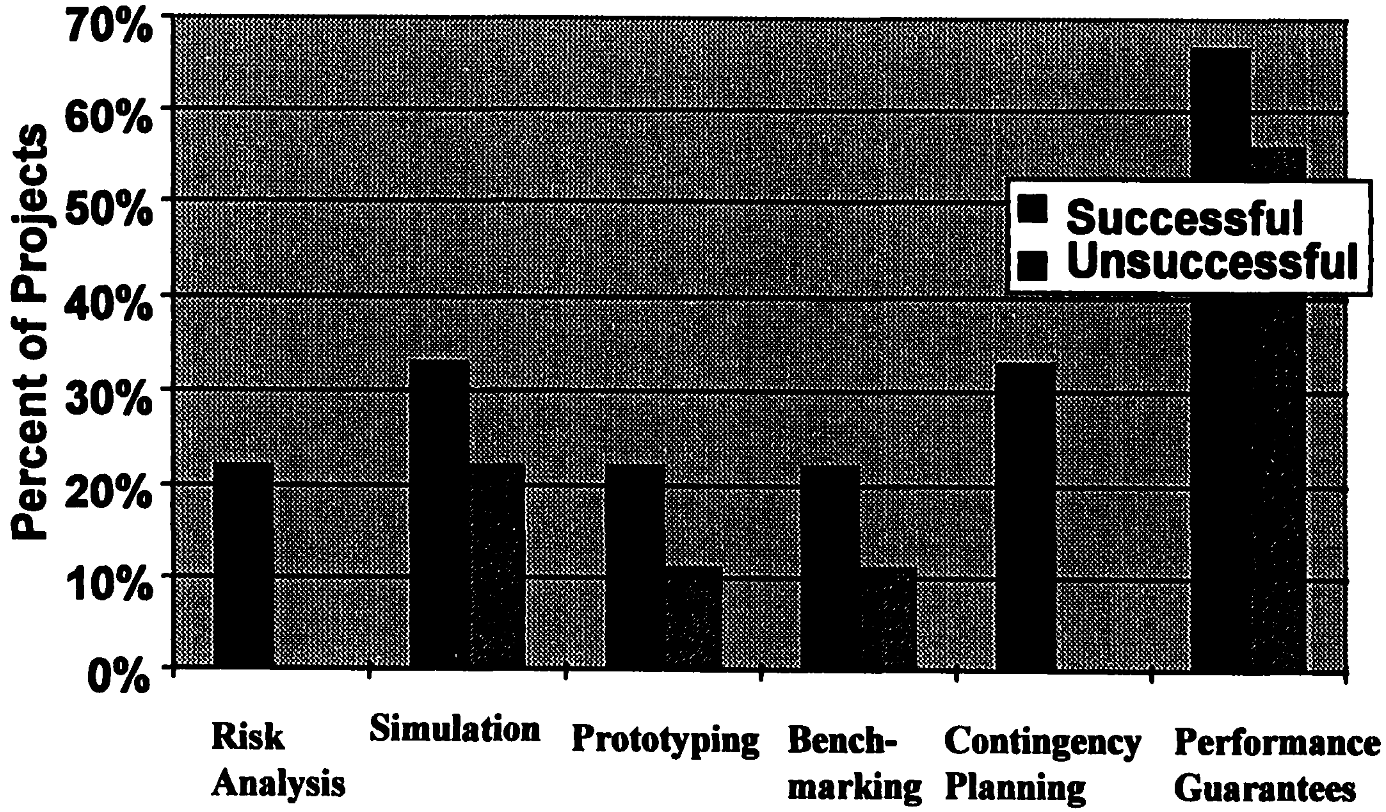


Figure 5.8

Table 5.5 - Techniques used for Risk Mgmt.

	Observation	Successful	Unsuccessful
	1	1	2
	2	3	1
	3	1	2
	4	5	1
	5	4	0
	6	1	1
	7	2	1
	8	1	1
	9	0	0
	Total	18	9
	Mean	2	1
	Std Dev	1.658312395	0.707106781
	90% Conf	0.90922649	0.38769569
	95% Conf	1.083408994	0.4619674
90% Conf	Min	1.09077351	
	Max		1.38769569
95% Conf	Min	0.916591006	
	Max		1.4619674

	80% Conf	0.708403687	0.302064513
80% Conf	Min	1.291596313	
	Max		1.302064513

T-test (homoscedastic):	0.115551021
T-test (paired):	0.159928491
T-test (homoscedastic, single tail):	0.057775511
T-test (paired, single tail):	0.079964245

Project Goals such as Schedule, Cost, Scope, and Product Quality

were more frequently considered absolutely fixed for successful projects than for unsuccessful projects.

(Confidence Level: 99%)

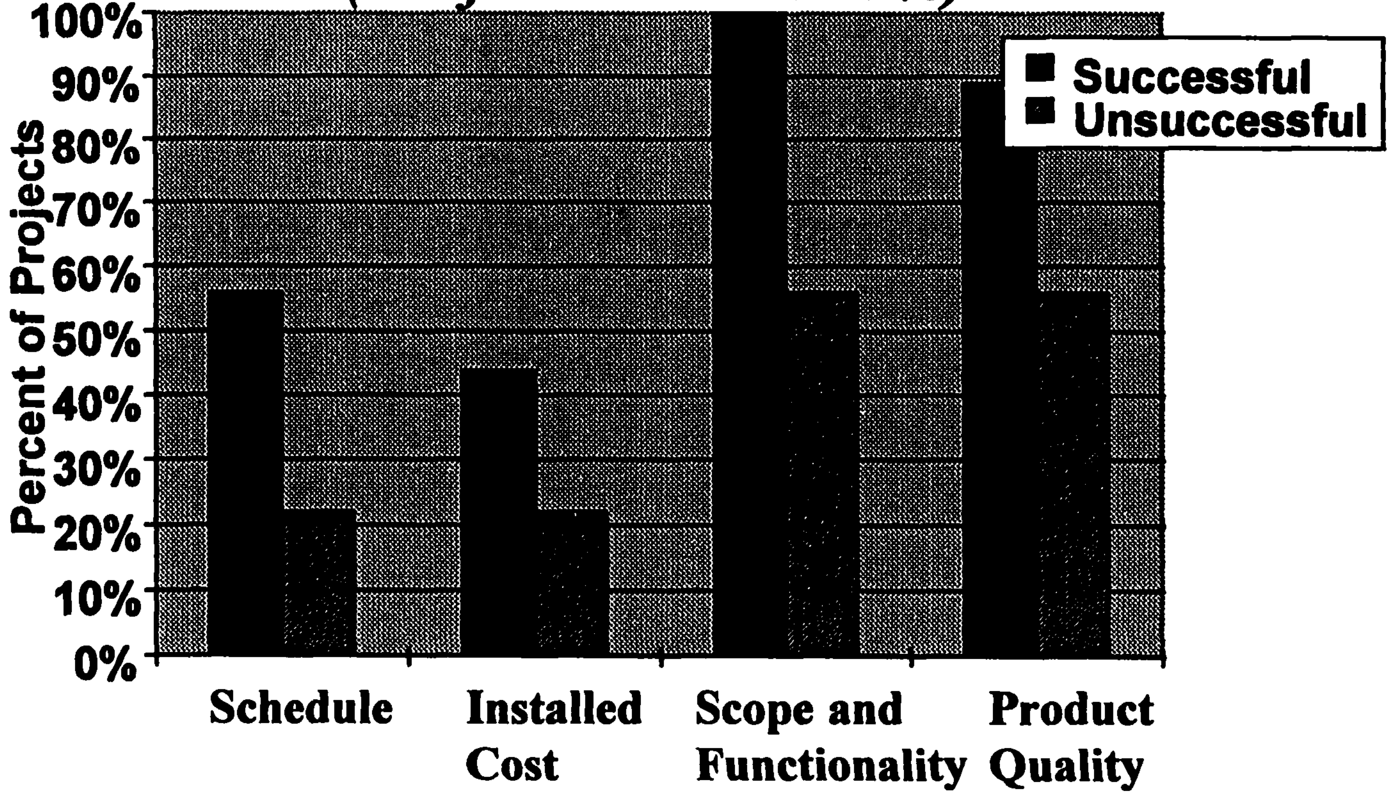


Figure 5.9

Table 5.6 - Goals Considered absolutely fixed

	Observation	Successful	Unsuccessful
	1	4	1
	2	2	2
	3	4	2
	4	4	1
	5	2	2
	6	2	1
	7	3	1
	8	3	2
	9	2	2
	Total	26	14
	Mean	2.888888889	1.555555556
	Std Dev	0.927960727	0.527046277
	90% Conf	0.508786478	0.288971065
	95% Conf	0.606255815	0.344329883
90% Conf	Min	2.38010241	
	Max		1.84452662
95% Conf	Min	2.282633074	
	Max		1.899885438

	99% Conf	0.796757991	0.452527759
99% Conf	Min	2.092130898	
	Max		2.008083315

T-test (homoscedastic):	0.001754525
T-test (paired):	0.011424554
T-test (homoscedastic, single tail):	0.000877262
T-test (paired, single tail):	0.005712277

<u>The Level of Executive Sponsoring</u> successful projects was significantly higher than the level sponsoring unsuccessful projects. (Confidence Level: 96%)

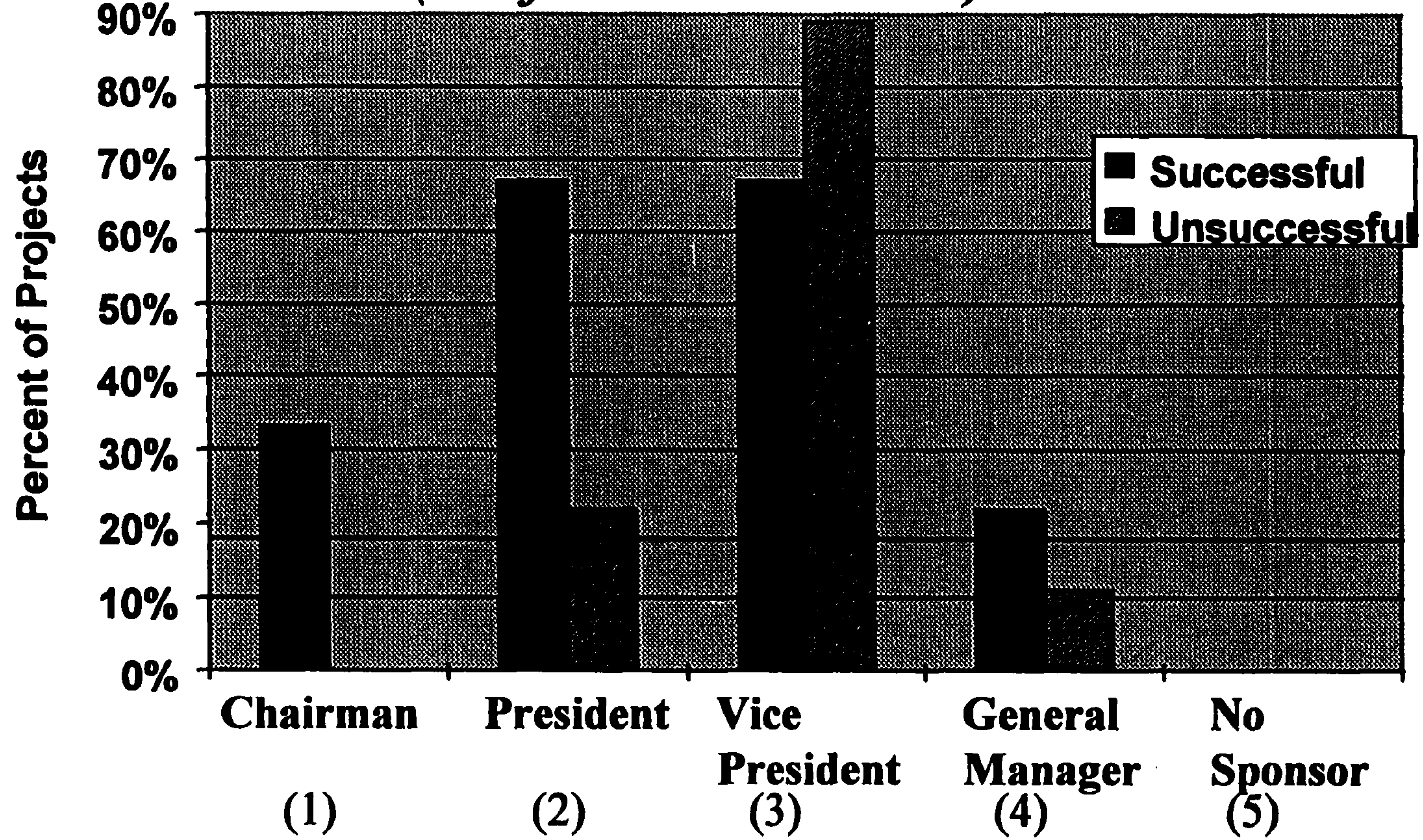


Figure 5.10

Table 5.7 - Level of Executive Champion For Project

	Observation	Successful	Unsuccessful
	1	1.5	3
	2	3	3
	3	3	3
	4	2.5	2
	5	2.5	2.5
	6	2	3
	7	2	3
	8	2	3
	9	3.5	3.5
	Total	22	26
	Mean	2.444444444	2.888888889
	Std Dev	0.634647759	0.416666667
	95% Conf	0.414628303	0.272216819
	90% Conf	0.347967424	0.228451807
	80% Conf	0.271111113	0.177993167
95% Conf	Min		2.61667207
	Max	2.859072747	
90% Conf	Min		2.660437081
	Max	2.792411868	
80% Conf	Min		2.710895722
	Max	2.715555558	

	80% Conf	0.271111113	0.177993167
80% Conf	Min		2.710895722
	Max	2.715555558	

T-test (homoscedastic):	0.098169176
T-test (paired):	0.086361186
T-test (homoscedastic, single tail):	0.049084588
T-test (paired, single tail):	0.043180593

The Background and Skills of The Project Managers

leading successful projects, were much broader than for those leading unsuccessful projects.

(Confidence Level: 100%)

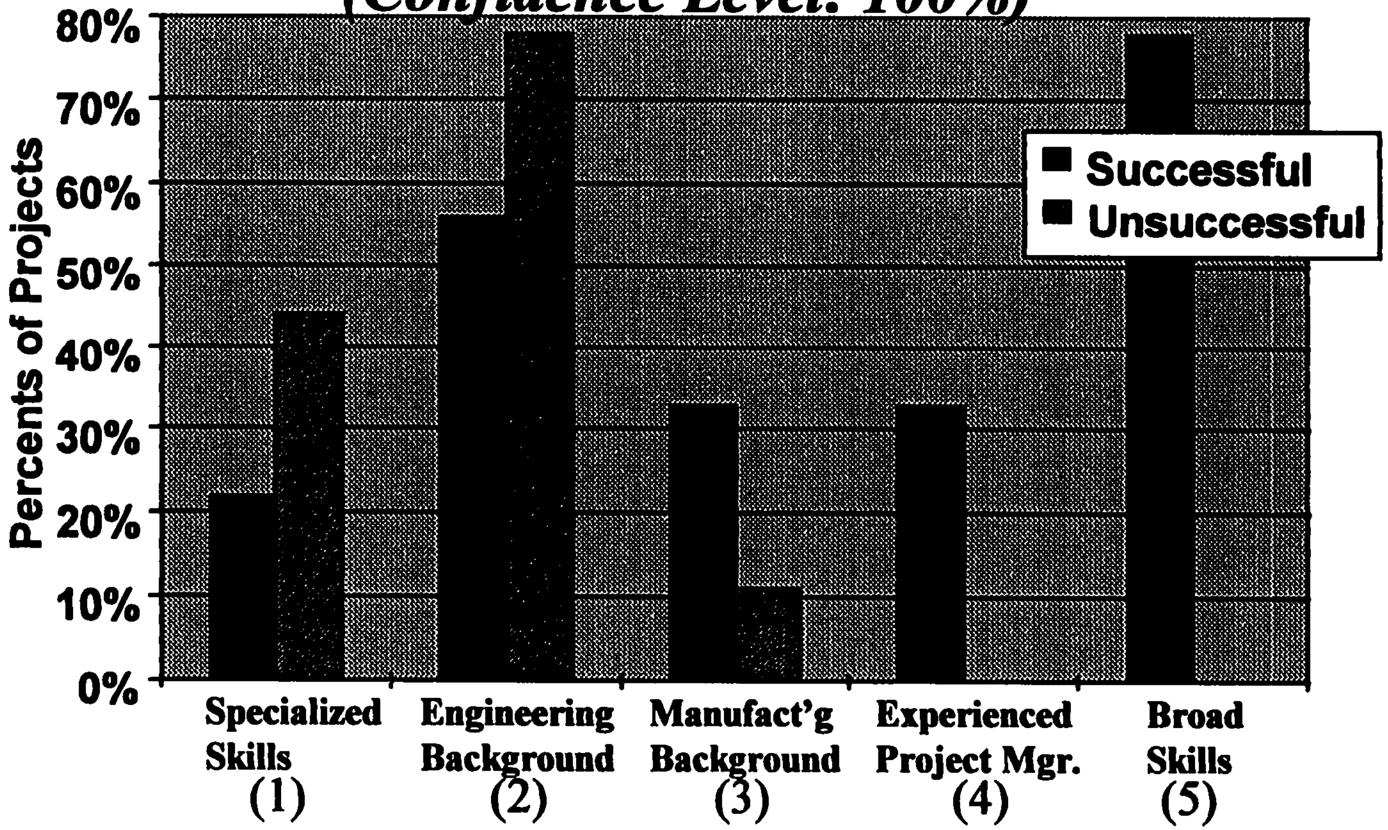


Figure 5.11

Table 5.8 - Background of Project Manager

	Observation	Successful	Unsuccessful
	1	5	1.5
	2	5	1.5
	3	5	2
	4	5	3
	5	5	1.5
	6	3	1
	7	5	2
	8	1	2
	9	5	2
	Total	39	16.5
	Mean	4.333333333	1.833333333
	Std Dev	1.414213562	0.559016994
	95% Conf	0.777183118	0.365217184
	90% Conf	0.65223335	0.30650026
	80% Conf	0.508173173	0.238802891
95% Conf	Min	3.556150216	
	Max		2.198550518
90% Conf	Min	3.681099983	
	Max		2.139833593
80% Conf	Min	3.82516016	
	Max		2.072136224

	99% Conf	1.021395331	0.479978422
99% Conf	Min	3.311938002	
	Max		2.313311756

T-test (homoscedastic):	0.000150153
T-test (paired):	0.000800312
T-test (homoscedastic, single tail):	7.50767E-05
T-test (paired, single tail):	0.000400156

<u>The Degree of Project Manager Empowerment</u>
was significantly higher for successful projects than for unsuccessful projects.
(Confidence Level: 99%)

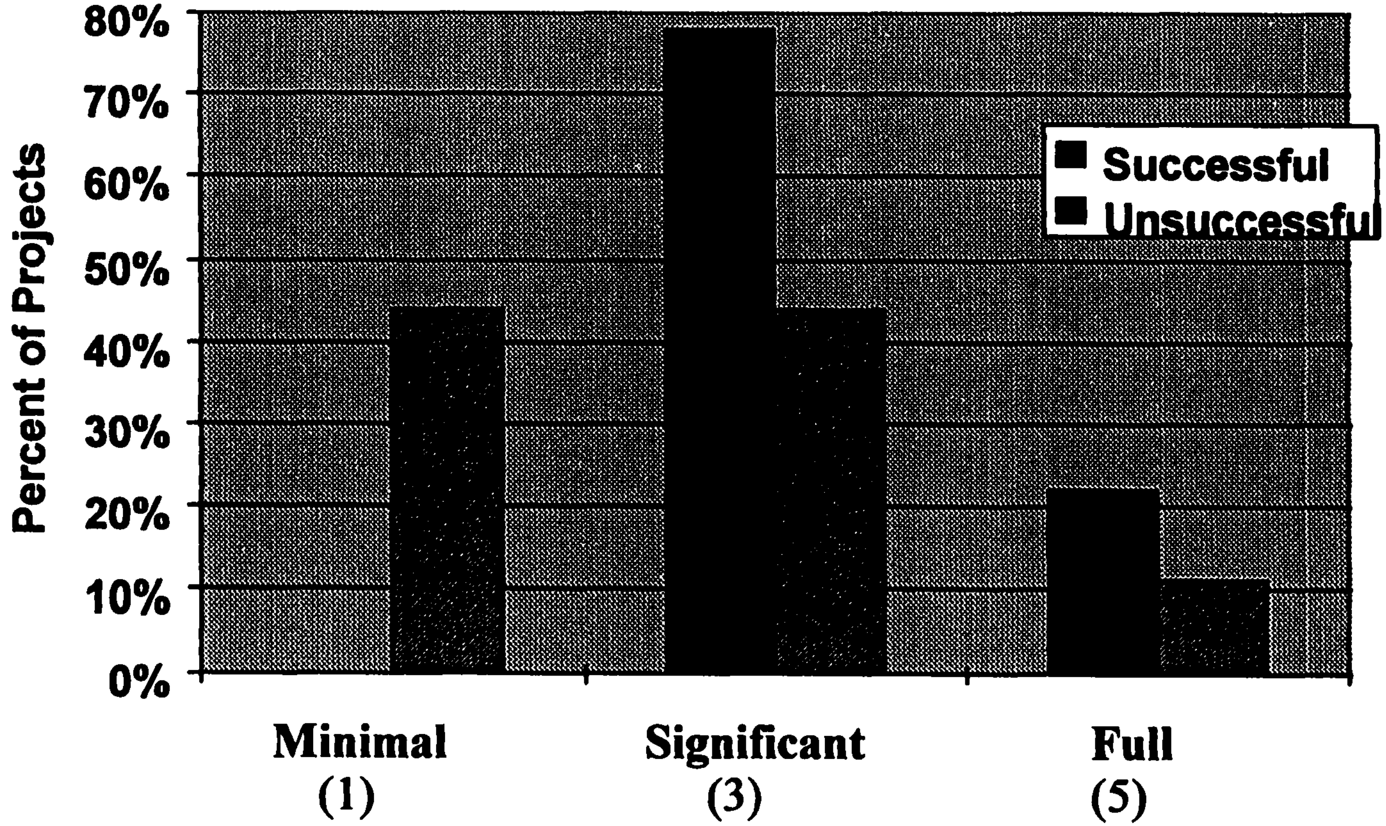


Figure 5.12

Table 5.9 - How empowered was the Project Manager

	Observation	Successful	Unsuccessful
	1	3	1
	2	3	1
	3	3	3
	4	5	5
	5	3	3
	6	3	1
	7	3	1
	8	5	3
	9	3	3
	Total	31	21
	Mean	3.444444444	2.333333333
	Std Dev	0.881917104	1.414213562
	95% Conf	0.576174333	0.923934801
	90% Conf	0.483541275	0.77539138
	80% Conf	0.376740477	0.604129025
95% Conf	Min	2.868270112	
	Max		3.257268134
90% Conf	Min	2.96090317	
	Max		3.108724714
80% Conf	Min	3.067703967	
	Max		2.937462358

	85% Conf	0.423182	0.678601171
85% Conf	Min	3.021262444	
	Max		3.011934504

T-test (homoscedastic):	0.062771963
T-test (paired):	0.013349063
T-test (homoscedastic, single tail):	0.031385981
T-test (paired, single tail):	0.006674532

Assigning a Project Manager Who Would Ultimately Manage
the new facility did not strongly correlate to project success.
(Confidence Level: 65%)

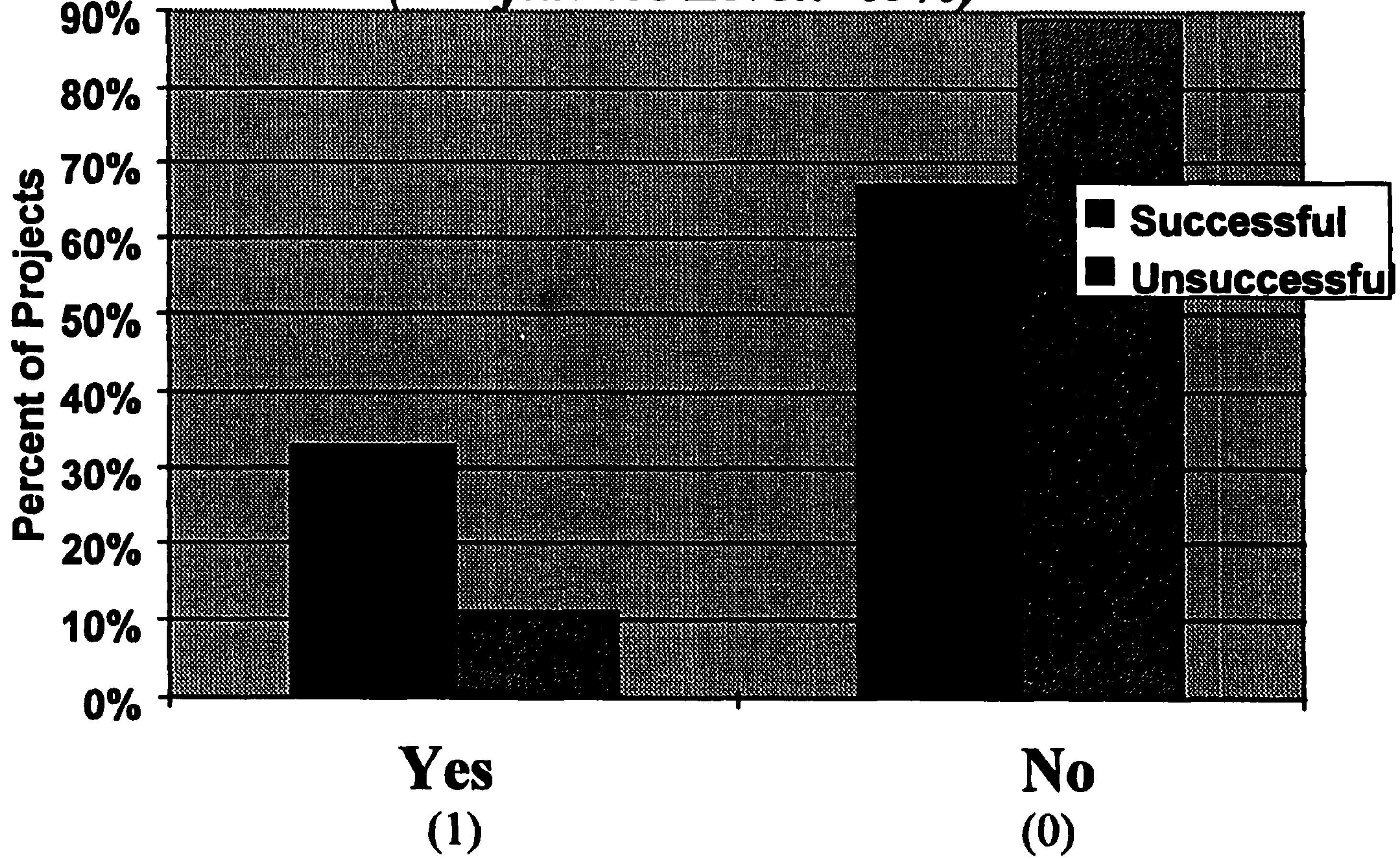


Figure 5.13

Table 5.10 - Project Manager To Ultimately Run Facility

	Observation	Successful	Unsuccessful
	1	0	0
	2	0	0
	3	0	0
	4	0	1
	5	0	0
	6	1	0
	7	1	0
	8	1	0
	9	0	0
	Total	3	1
	Mean	0.333333333	0.111111111
	Std Dev	0.5	0.333333333
	95% Conf	0.32666018	0.217773432
	90% Conf	0.274142167	0.182761426
	80% Conf	0.213591799	0.142394518
95% Conf	Min	0.006673153	
	Max		0.328884543
90% Conf	Min	0.059191167	
	Max		0.293872537
80% Conf	Min	0.119741534	
	Max		0.25350563

	60% Conf	0.140270231	0.093513478
60% Conf	Min	0.193063102	
	Max		0.204624589

T-test (homoscedastic):	0.283654224
T-test (paired):	0.346593507
T-test (homoscedastic, single tail):	0.141827112
T-test (paired, single tail):	0.173296754

Projects Utilizing Full Time Co-located Project Teams *were more successful than projects utilizing part time project support staffs.*
(Confidence Level: 99%)

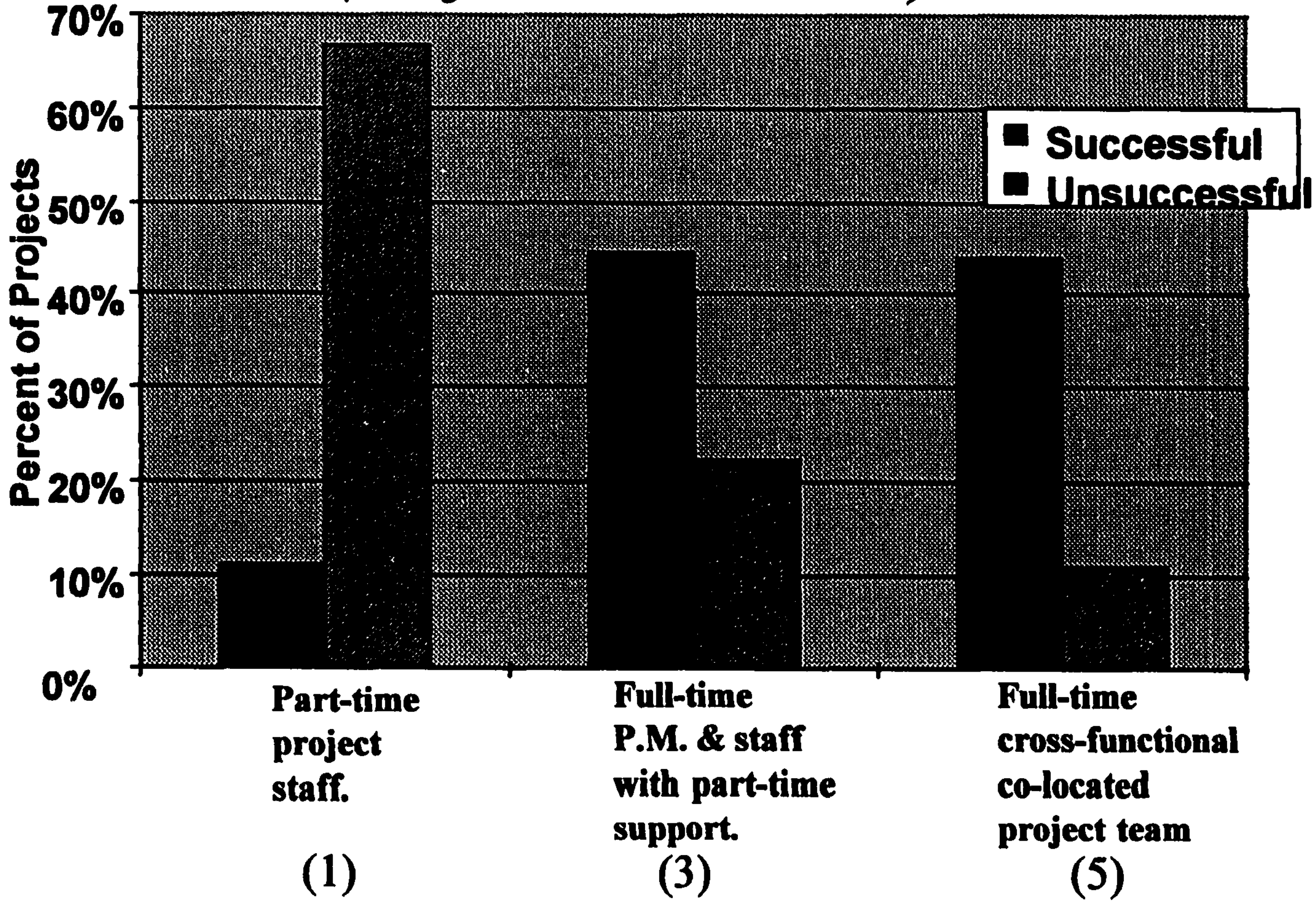


Figure 5.14

Table 5.11 - Project Team Structure and Location

	Observation	Successful	Unsuccessful
	1	3	3
	2	3	3
	3	5	1
	4	5	5
	5	3	1
	6	5	1
	7	5	1
	8	1	1
	9	3	1
	Total	33	17
	Mean	3.666666667	1.888888889
	Std Dev	1.414213562	1.452966315
	95% Conf	0.923934801	0.949252271
	90% Conf	0.77539138	0.796638495
	80% Conf	0.604129025	0.620683244
95% Conf	Min	2.742731866	
	Max		2.83814116
90% Conf	Min	2.891275286	
	Max		2.685527384
80% Conf	Min	3.062537642	
	Max		2.509572133

	94% Conf	0.88661298	0.910907765
94% Conf	Min	2.780053687	
	Max		2.799796654

T-test (homoscedastic):	0.0181818
T-test (paired):	0.020711387
T-test (homoscedastic, single tail):	0.0090909
T-test (paired, single tail):	0.010355694

<u>The Level of Design and Purchase Specification Detail</u>
which owners used did not correlate with project success.
<u>(Confidence Level: 41%)</u>

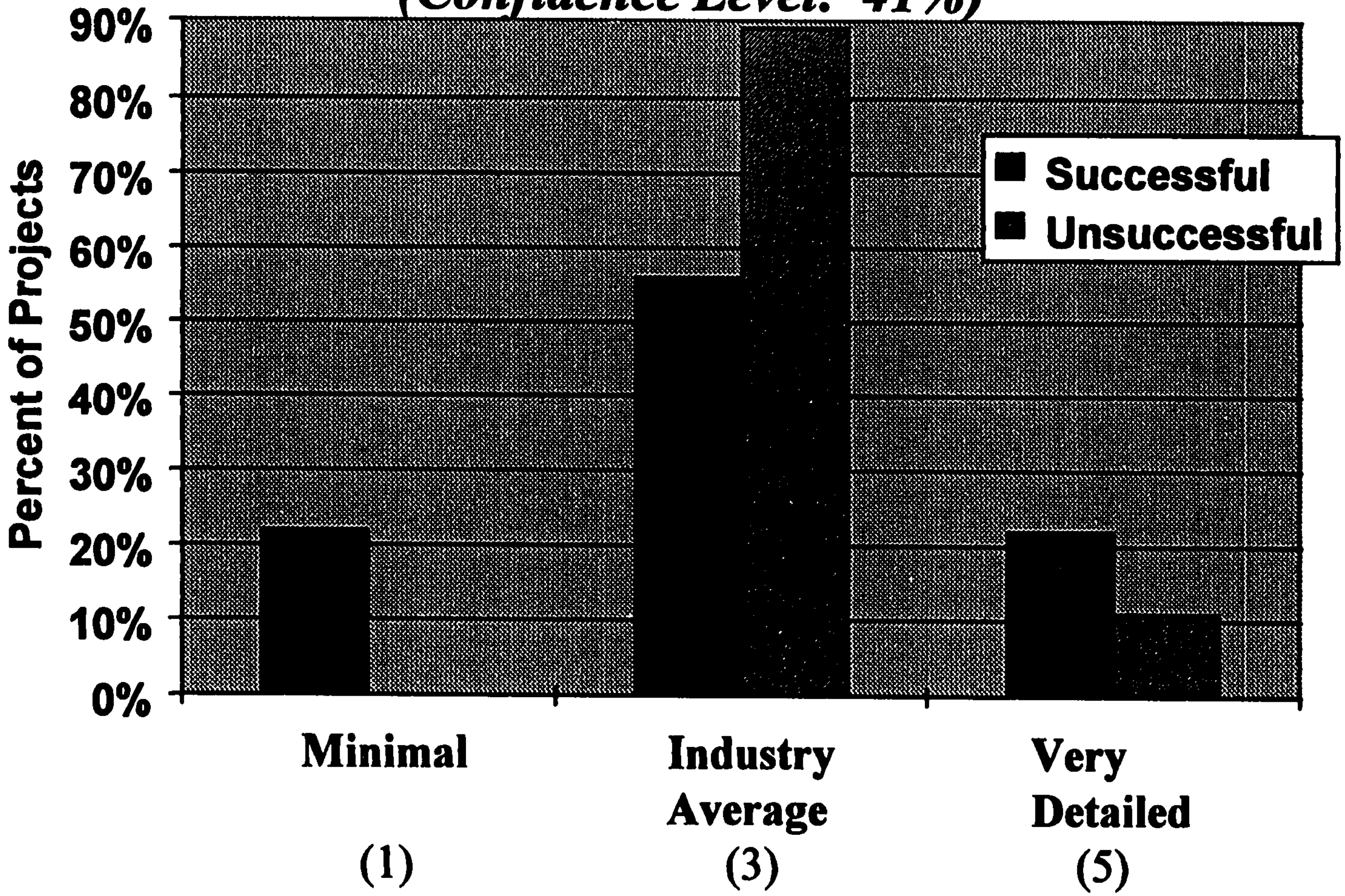


Figure 5.15

Table 5.12 - Detail of Specifications and standards

	Observation	Successful	Unsuccessful
	1	5	5
	2	1	3
	3	3	3
	4	5	3
	5	3	3
	6	1	3
	7	3	3
	8	3	3
	9	3	3
	Total	27	29
	Mean	3	3.222222222
	Std Dev	1.414213562	0.666666667
	95% Conf	0.923934801	0.435547125
	90% Conf	0.77539138	0.365523072
	80% Conf	0.604129025	0.284789208
95% Conf	Min		2.786675097
	Max	3.923934801	
90% Conf	Min		2.85669915
	Max	3.77539138	
80% Conf	Min		2.937433014
	Max	3.604129025	

	30% Conf	0.181642152	0.085626948
30% Conf	Min		3.136595274
	Max	3.181642152	

T-test (homoscedastic):	0.675496816
T-test (paired):	0.594264016
T-test (homoscedastic, single tail):	0.337748408
T-test (paired, single tail):	0.297132008

<u>The Level of Detail Used in Engineering Drawings</u> ***did not strongly correlate to project success, although there was a slight trend towards successful projects using more detail.***
(Confidence Level: 72%)

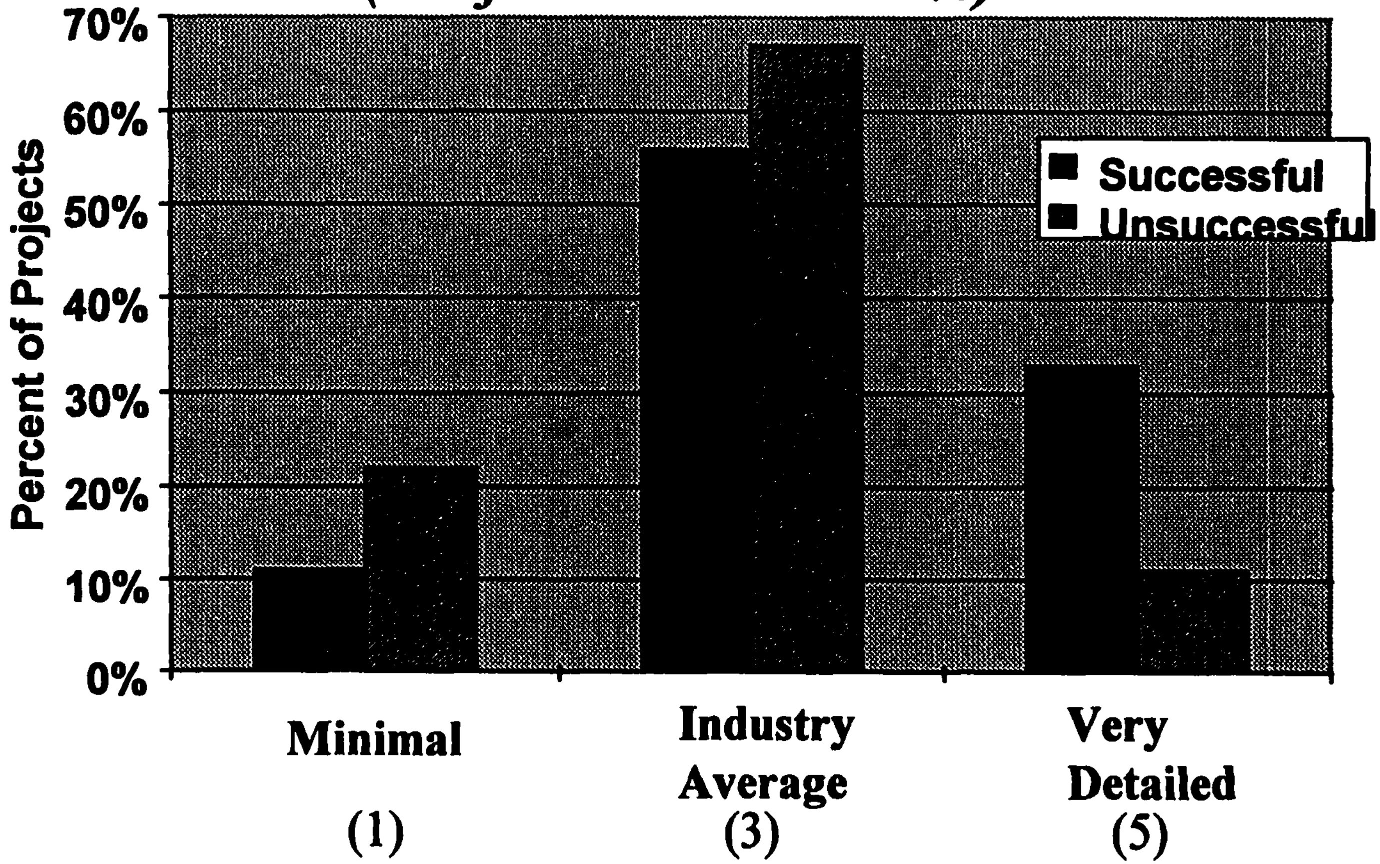


Figure 5.16

Table 5.13 - Detail of Engineering Drawings

	Observation	Successful	Unsuccessful
	1	5	3
	2	5	1
	3	3	1
	4	5	5
	5	3	3
	6	1	3
	7	3	3
	8	3	3
	9	3	3
	Total	31	25
	Mean	3.444444444	2.777777778
	Std Dev	1.333333333	1.201850425
	95% Conf	0.871093597	0.785193076
	90% Conf	0.731045595	0.658955526
	80% Conf	0.569577988	0.513410607
95% Conf	Min	2.573350848	
	Max		3.562970853
90% Conf	Min	2.713398849	
	Max		3.436733304
80% Conf	Min	2.874866456	
	Max		3.291188385

	57% Conf	0.350751597	0.316163184
57% Conf	Min	3.093692848	
	Max		3.093940962

T-test (homoscedastic):	0.281662995
T-test (paired):	0.28153692
T-test (homoscedastic, single tail):	0.140831498
T-test (paired, single tail):	0.14076846

<u>The Source of Engineering Services</u> did not strongly correlate to project success, however unsuccessful projects tended to rely more heavily on equipment suppliers and major outside engineering firms (Confidence Level: 86%)

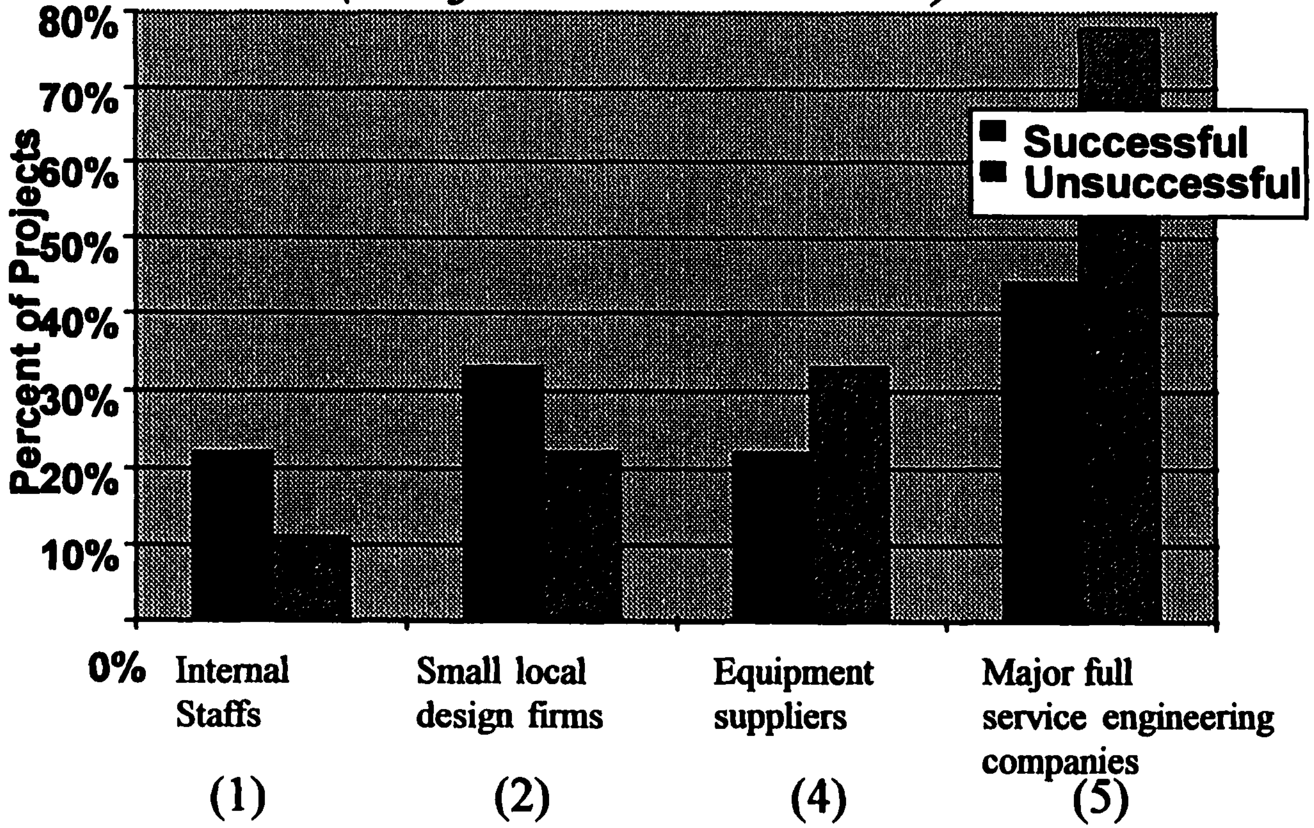


Figure 5.17

Table 5.14 - Source of Engineering for Project

	Observation	Successful	Unsuccessful
	1	5	4.5
	2	1	3
	3	4	4.5
	4	5	5
	5	2	5
	6	2.333333333	3
	7	5	5
	8	2	2
	9	5	5
	Total	31.33333333	37
	Mean	3.481481481	4.111111111
	Std Dev	1.633937908	1.139566194
	95% Conf	1.067484904	0.744501797
	90% Conf	0.895862557	0.624806291
	80% Conf	0.697991475	0.486803987
95% Conf	Min		3.366609314
	Max	4.548966385	
90% Conf	Min		3.48630482
	Max	4.377344038	
80% Conf	Min		3.624307124
	Max	4.179472956	

	55% Conf	0.411433697	0.286948439
55% Conf	Min		3.824162672
	Max	3.892915179	

T-test (homoscedastic):	0.357129541
T-test (paired):	0.135794425
T-test (homoscedastic, single tail):	0.178564771
T-test (paired, single tail):	0.067897212

The Level of In-house Engineering Expertise

available to successful projects was significantly higher than that available to unsuccessful projects.

(Confidence Level: 98%)

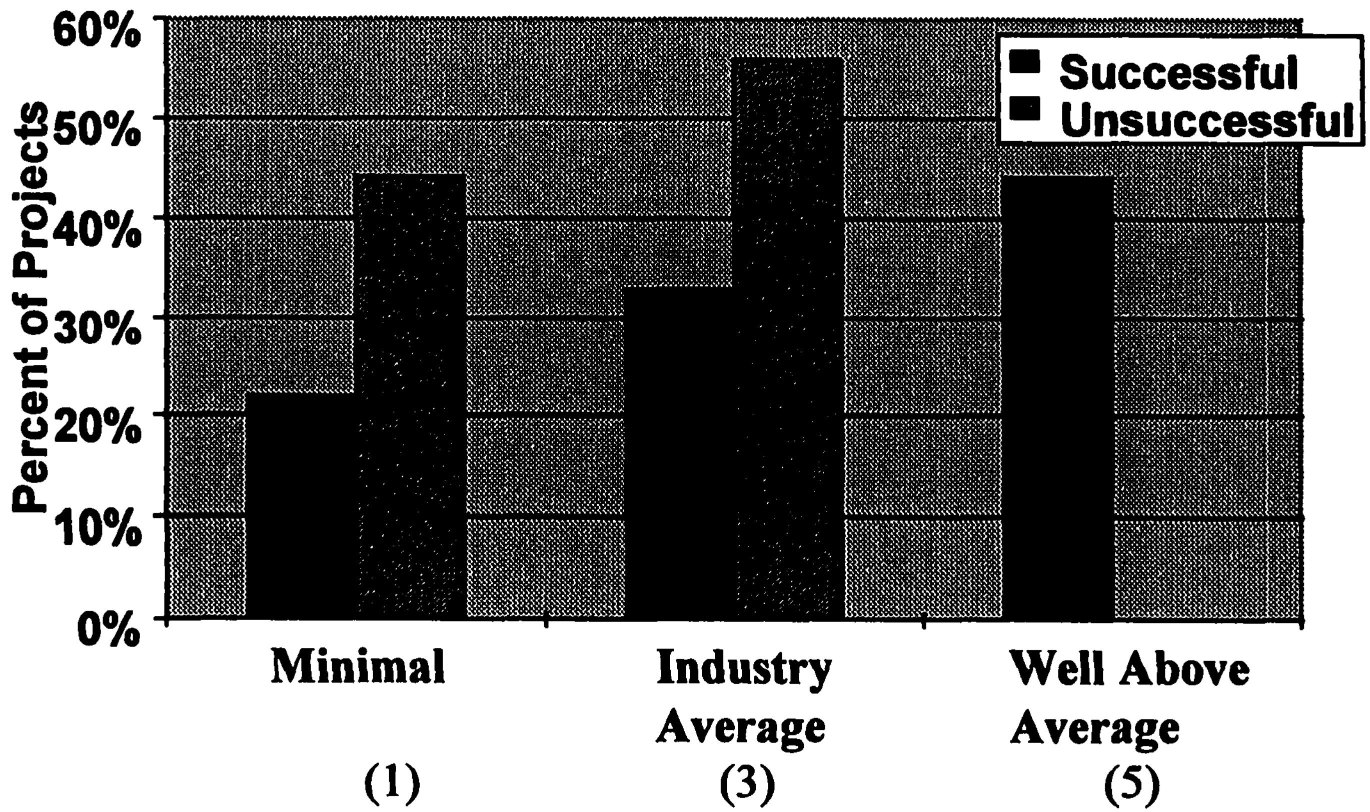


Figure 5.18

Table 5.15 - Amount of in-house engineering expertise.

	Observation	Successful	Unsuccessful
	1	5	1
	2	3	3
	3	1	1
	4	5	3
	5	1	1
	6	5	1
	7	3	3
	8	3	3
	9	5	3
	Total	31	19
	Mean	3.444444444	2.111111111
	Std Dev	1.666666667	1.054092553
	95% Conf	1.08886729	0.688660419
	90% Conf	0.913807241	0.577942678
	80% Conf	0.711972678	0.45029124
95% Conf	Min	2.355577155	
	Max		2.79977153
90% Conf	Min	2.530637204	
	Max		2.689053789
80% Conf	Min	2.732471767	
	Max		2.561402352

	85% Conf	0.799738918	0.505799507
85% Conf	Min	2.644705526	
	Max		2.616910618

T-test (homoscedastic):	0.059507392
T-test (paired):	0.049735563
T-test (homoscedastic, single tail):	0.029753696
T-test (paired, single tail):	0.024867781

<u>The Level of Process Control and Automation</u> did not strongly correlate to project success, however successful projects tended to incorporate higher levels of automation.
(Confidence Level: 83%)

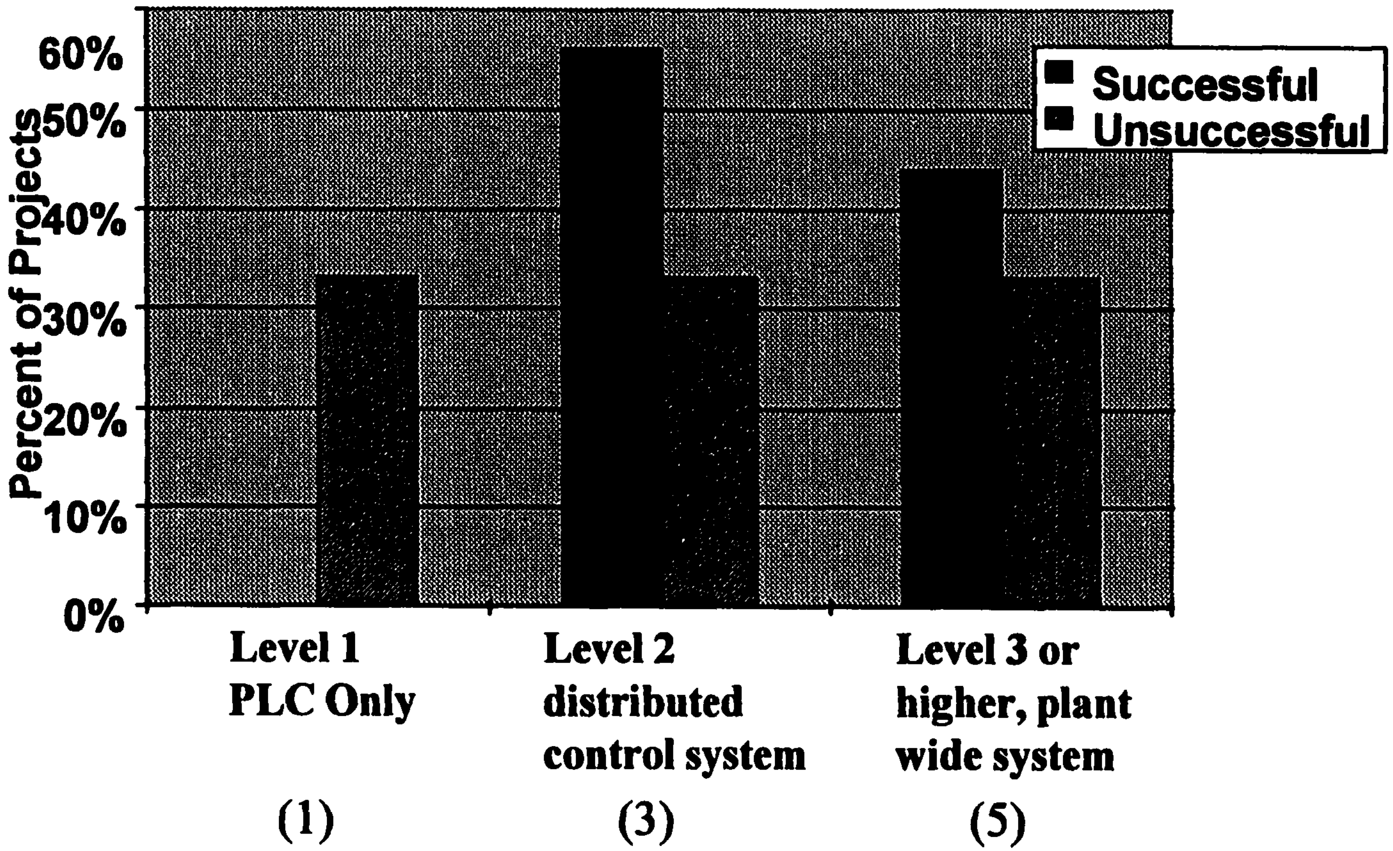


Figure 5.19

Table 5.16 - PC/Automation used on project

	Observation	Successful	Unsuccessful
	1	5	5
	2	3	5
	3	3	3
	4	5	3
	5	3	1
	6	3	3
	7	5	5
	8	5	1
	9	3	1
	Total	35	27
	Mean	3.888888889	3
	Std Dev	1.054092553	1.732050808
	95% Conf	0.688660419	1.131584184
	90% Conf	0.577942678	0.949656428
	80% Conf	0.45029124	0.739903778
95% Conf	Min	3.20022847	
	Max		4.131584184
90% Conf	Min	3.310946211	
	Max		3.949656428
80% Conf	Min	3.438597648	
	Max		3.739903778

	70% Conf	0.364165547	0.598384867
70% Conf	Min	3.524723342	
	Max		3.598384867

T-test (homoscedastic):	0.20698309
T-test (paired):	0.169020203
T-test (homoscedastic, single tail):	0.103491545
T-test (paired, single tail):	0.084510102

<u>The Amount of "External" Customer Involvement</u>
did not correlate to the degree of project success.
(Confidence Level: 0%)

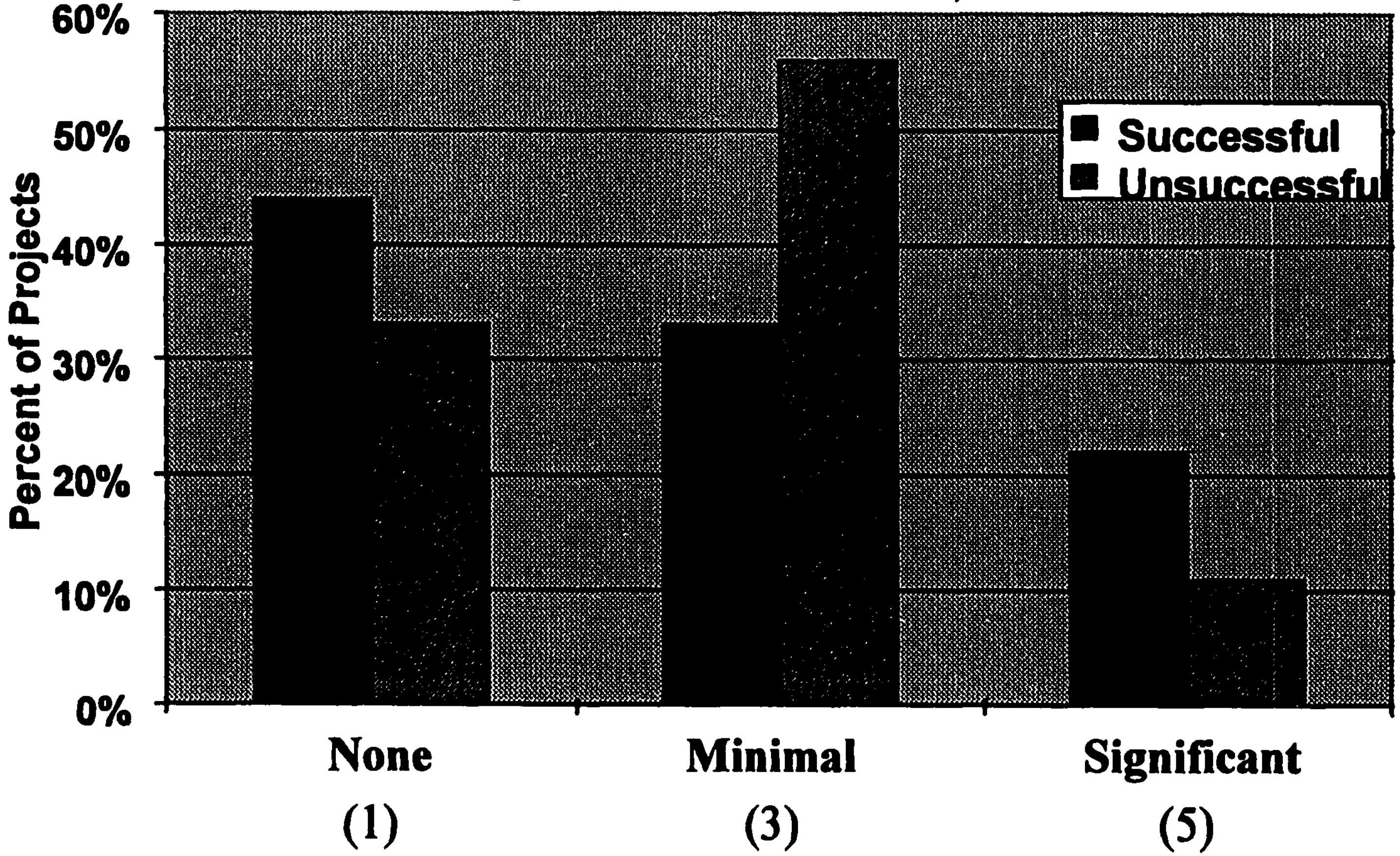


Figure 5.20

Table 5.17 - Level of customer involvement

	Observation	Successful	Unsuccessful
	1	5	1
	2	3	3
	3	1	3
	4	5	3
	5	1	1
	6	1	1
	7	3	3
	8	1	5
	9	3	3
	Total	23	23
	Mean	2.555555556	2.555555556
	Std Dev	1.666666667	1.333333333
	95% Conf	1.08886729	0.871093597
	90% Conf	0.913807241	0.731045595
	80% Conf	0.711972678	0.569577988
95% Conf	Min	1.466688266	
	Max		3.426649152
90% Conf	Min	1.641748315	
	Max		3.286601151
80% Conf	Min	1.843582878	
	Max		3.125133544

	1% Conf	0.006962687	0.005570148
1% Conf	Min	2.548592868	
	Max		2.561125704

T-test (homoscedastic):	1.00000000
T-test (paired):	1
T-test (homoscedastic, single tail):	0.5
T-test (paired, single tail):	0.5

<u>The Involvement of Key Operating Associates</u>
occurred earlier and more extensively during successful projects than during unsuccessful projects.
(Confidence Level: 100%)

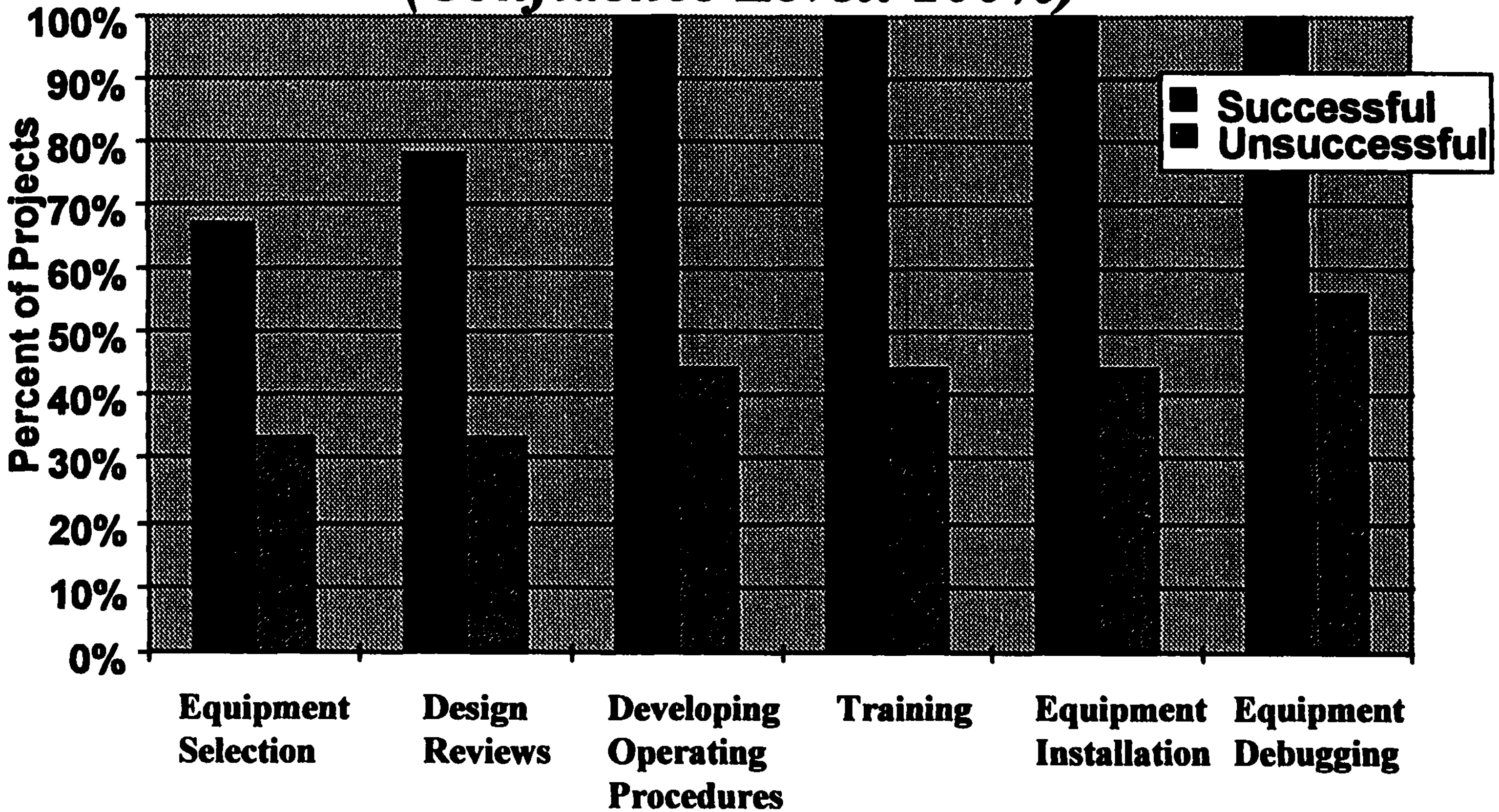


Figure 5.21

Table 5.18 - Operator involvement in project

	Observation	Successful	Unsuccessful
	1	6	5
	2	6	6
	3	4	3
	4	6	0
	5	6	0
	6	6	2
	7	5	0
	8	4	1
	9	6	6
	Total	49	23
	Mean	5.444444444	2.555555556
	Std Dev	0.881917104	2.554951619
	90% Conf	0.483541329	1.400839946
	95% Conf	0.576174398	1.669201913
90% Conf	Min	4.960903115	
	Max		3.956395501
95% Conf	Min	4.868270047	
	Max		4.224757469

	99% Conf	0.757224168	2.193710854
99% Conf	Min	4.687220276	
	Max		4.74926641

T-test (homoscedastic):	0.00550252
T-test (paired):	0.008010251
T-test (homoscedastic, single tail):	0.00275126
T-test (paired, single tail):	0.004005126

The Involvement of Key Maintenance Associates

occurred earlier and more extensively during successful projects than during unsuccessful projects.

(Confidence Level: 100%)

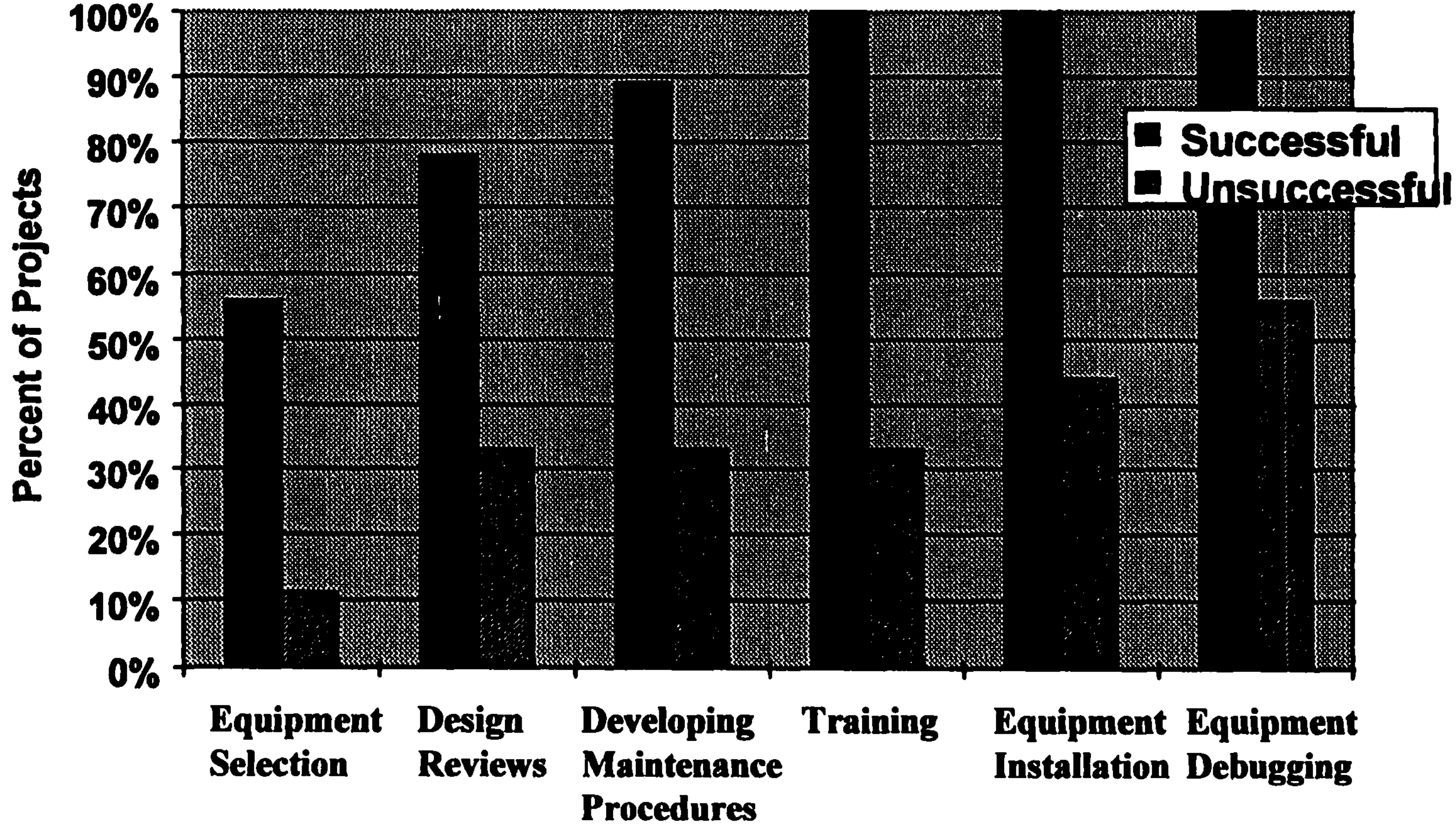


Figure 5.22

Table 5.19 - Maintenance Involvement in project

	Observation	Successful	Unsuccessful
	1	6	4
	2	6	6
	3	3	1
	4	6	0
	5	6	0
	6	6	1
	7	5	0
	8	4	2
	9	5	5
	Total	47	19
	Mean	5.222222222	2.111111111
	Std Dev	1.092906421	2.315407332
	90% Conf	0.599223457	1.269501384
	95% Conf	0.714018004	1.512702753
90% Conf	Min	4.622998765	
	Max		3.380612495
95% Conf	Min	4.508204219	
	Max		3.623813865

	99% Conf	0.938382009	1.988035374
99% Conf	Min	4.283840213	
	Max		4.099146485

T-test (homoscedastic):	0.002180305
T-test (paired):	0.004841731
T-test (homoscedastic, single tail):	0.001090152
T-test (paired, single tail):	0.002420866

Supplier Performance Incentives *were more frequently used in successful projects than in unsuccessful projects.*
(Confidence Level: 96%)

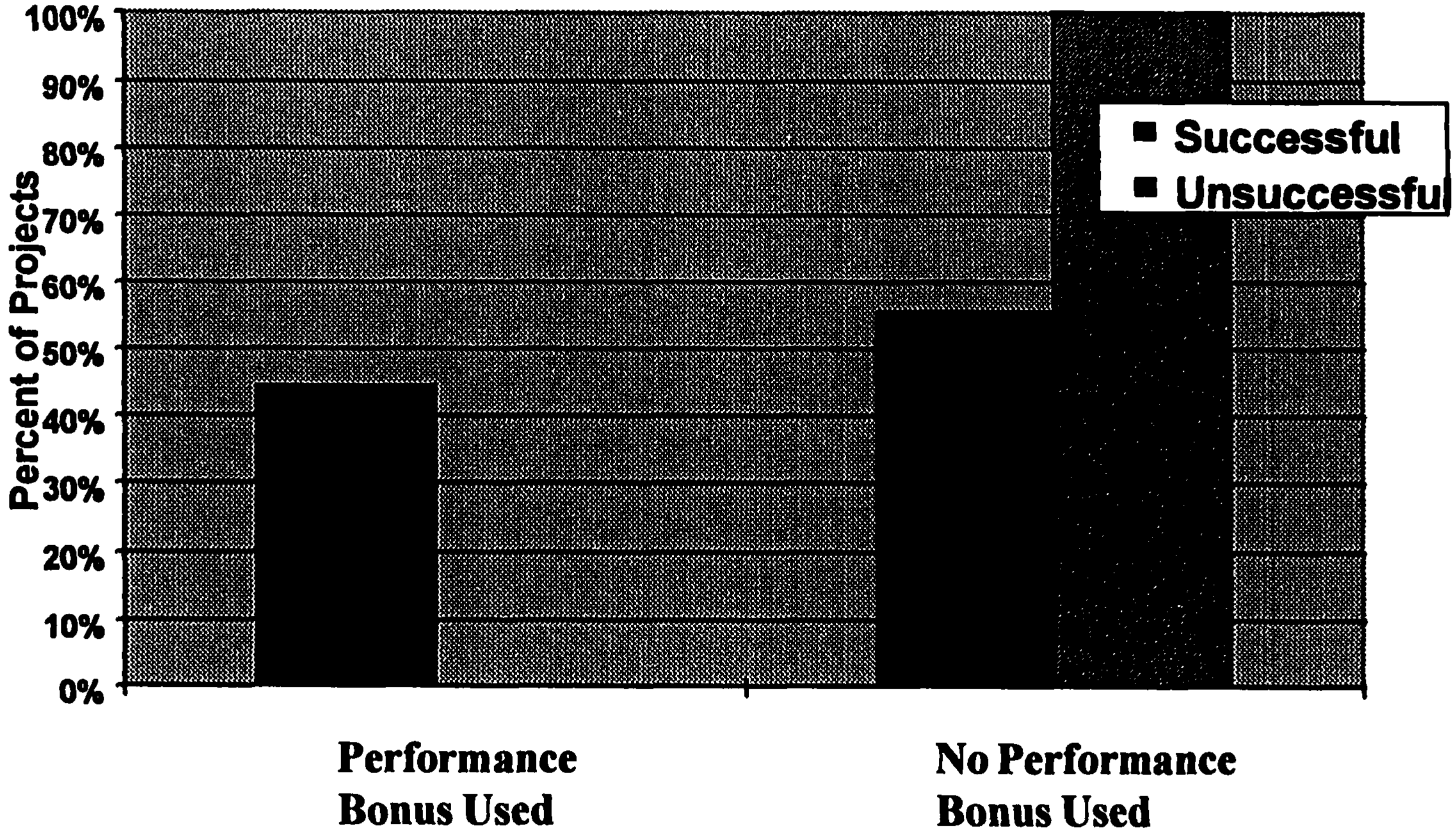


Figure 5.23

Table 5.20 - Use of Performance Incentives

	Observation	Successful	Unsuccessful
	1	1	0
	2	1	0
	3	1	0
	4	1	0
	5	0	0
	6	0	0
	7	0	0
	8	0	0
	9	0	0
	Total	4	0
	Mean	0.444444444	0
	Std Dev	0.527046277	0
	90% Conf	0.599223457	1.269501384
	95% Conf	0.714018004	1.512702753
90% Conf	Min	-0.154779013	
	Max		1.269501384
95% Conf	Min	-0.269573559	
	Max		1.512702753

	99% Conf	0.938382009	1.988035374
99% Conf	Min	-0.493937564	
	Max		1.988035374

T-test (homoscedastic):	0.022293586
T-test (paired):	0.035265203
T-test (homoscedastic, single tail):	0.011146793
T-test (paired, single tail):	0.017632602

The Use of Turn-key Contracts

showed no correlation to the level of project success.

(Confidence Level: 0%)

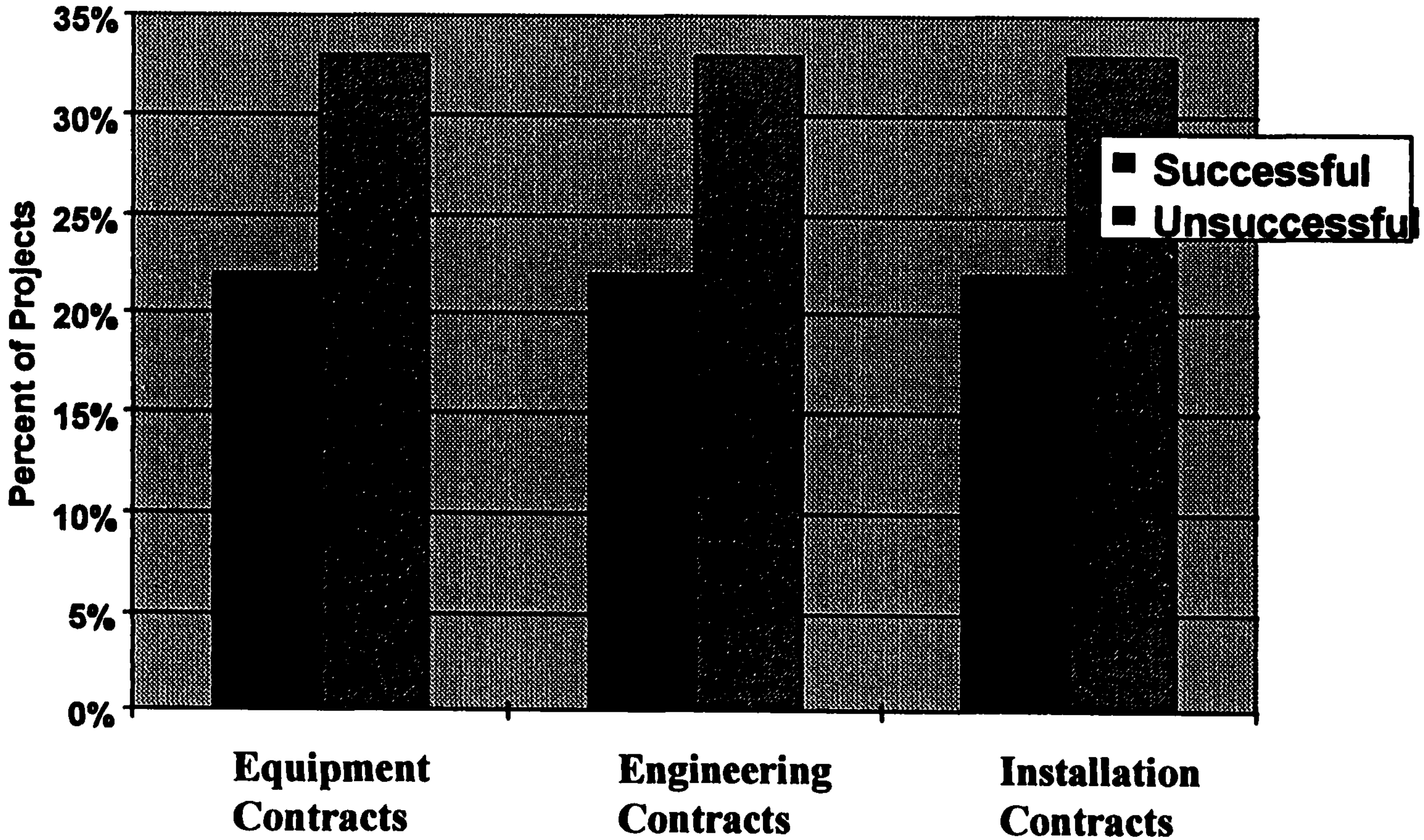


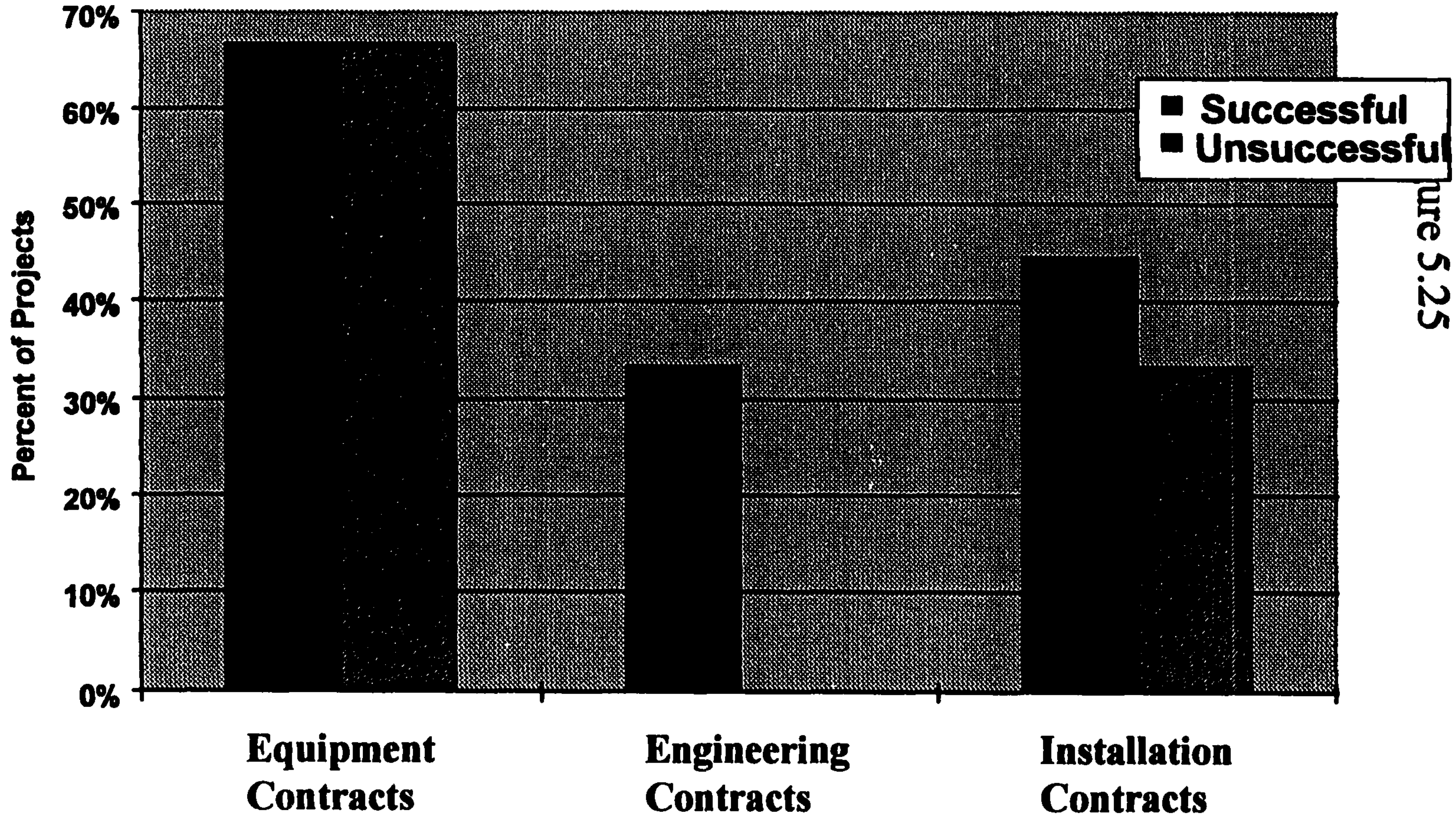
Figure 5.24

Table 5.21 - Use of Turnkey Contracts

	Observation	Successful	Unsuccessful
	1	3	3
	2	0	0
	3	3	0
	4	0	0
	5	0	0
	6	0	0
	7	0	0
	8	0	3
	9	0	0
	Total	6	6
	Mean	0.666666667	0.666666667
	Std Dev	1.322875656	1.322875656
	90% Conf	0.599223457	1.269501384
	95% Conf	0.714018004	1.512702753
90% Conf	Min	0.06744321	
	Max		1.93616805
95% Conf	Min	-0.047351337	
	Max		2.17936942
	99% Conf	0.938382009	1.988035374
99% Conf	Min	-0.271715342	
	Max		2.65470204

T-test (homoscedastic):	1
T-test (paired):	1
T-test (homoscedastic, single tail):	0.5
T-test (paired, single tail):	0.5

<u>The General Use of Fixed Price Contracts</u>* did not strongly correlate to project success, however successful projects made greater use of fixed price contracts for engineering services. *(Confidence Level: 73%)



ure 5.25

Table 5.22 - Use of Fixed Price Contracts

	Observation	Successful	Unsuccessful
	1	0	0
	2	1	1
	3	0	1
	4	2	2
	5	3	2
	6	1	0
	7	1	1
	8	2	2
	9	3	0
	Total	13	9
	Mean	1.444444444	1
	Std Dev	1.130388331	0.866025404
	90% Conf	0.599223457	1.269501384
	95% Conf	0.714018004	1.512702753
90% Conf	Min	0.845220987	
	Max		2.269501384
95% Conf	Min	0.730426441	
	Max		2.512702753

	99% Conf	0.938382009	1.988035374
99% Conf	Min	0.506062436	
	Max		2.988035374

T-test (homoscedastic):	0.363022454
T-test (paired):	0.272070466
T-test (homoscedastic, single tail):	0.181511227
T-test (paired, single tail):	0.136035233

The Use of Time and Material Contracts

did not correlate to project success.

(Confidence Level: 22%)

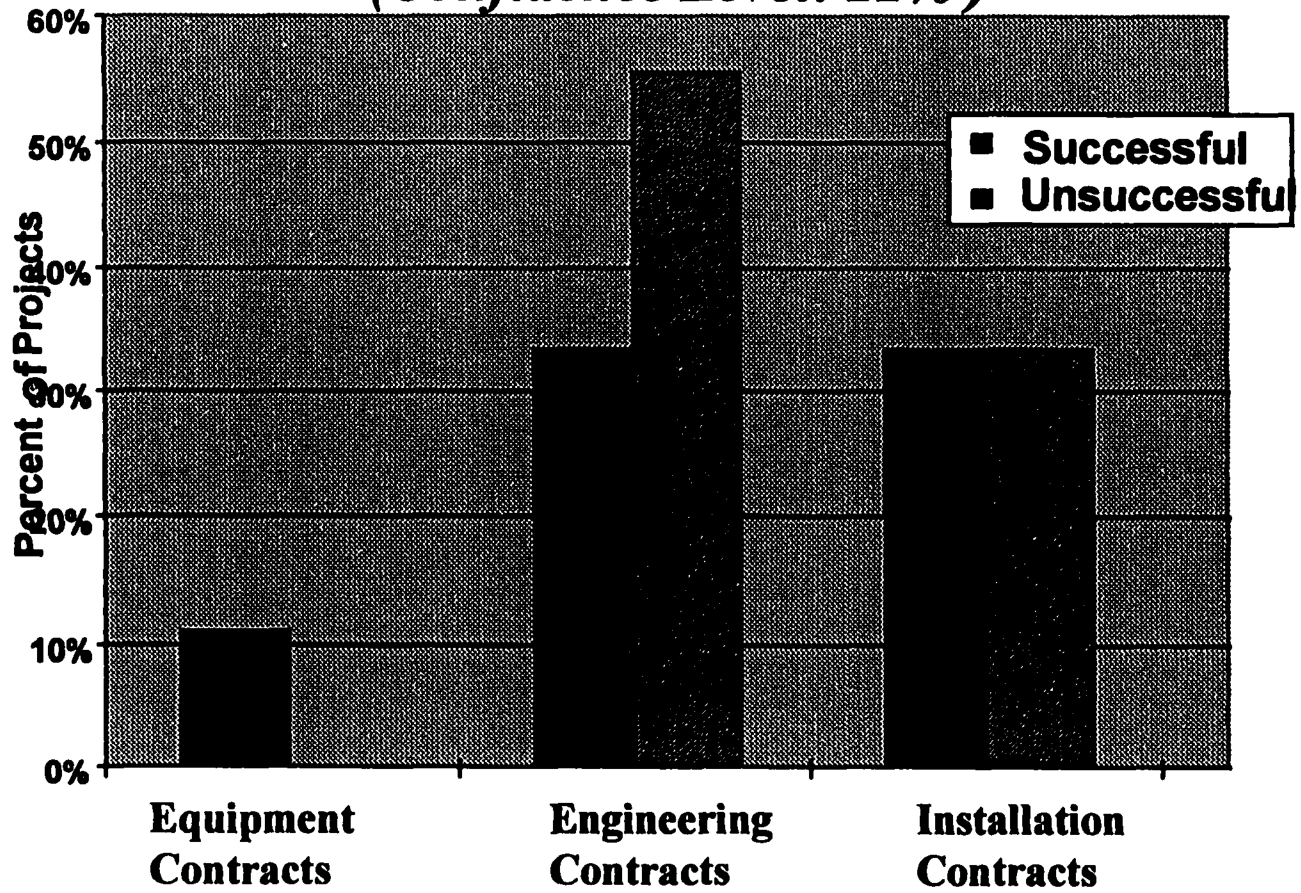


Figure 5.26

Table 5.23 - Use of Time & Materials Contracts

	Observation	Successful	Unsuccessful
	1	0	0
	2	1	2
	3	0	2
	4	1	1
	5	0	1
	6	2	0
	7	2	2
	8	1	0
	9	0	0
	Total	7	8
	Mean	0.777777778	0.888888889
	Std Dev	0.833333333	0.927960727
	90% Conf	0.599223457	1.269501384
	95% Conf	0.714018004	1.512702753
90% Conf	Min	0.178554321	
	Max		2.158390273
95% Conf	Min	0.063759774	
	Max		2.401591642

	99% Conf	0.938382009	1.988035374
99% Conf	Min	-0.160604231	
	Max		2.876924263

T-test (homoscedastic):	0.792682366
T-test (paired):	0.782355279
T-test (homoscedastic, single tail):	0.396341183
T-test (paired, single tail):	0.391177639

Chapter 6

Discussion of Results

The following Table 6.1 lists the critical success factors ranked by the probabilities derived from the statistical analyses presented in the previous chapter. The factors listed first are those whose degree of presence in successful and non-successful projects differed most significantly. It is important to note that this ranking does not directly indicate the relative magnitude of impact which each of these factors had on project success. It does however represent how distinct each factor was to successful projects, or conversely failed projects. One can conclude however, that if the degree which a factor differed from successful to unsuccessful projects was beyond that explainable through random occurrence, then the factor was significant to the outcome of the project.

Table 6.1 Critical Success Factor Confidence Ranking

	Critical Success Factor	T-Test Homoscedastic	Paired T-test (Single Tail)	Paired T-test (Double Tail)	Confidence Level
1	Project Manager Background and Skills	0.000150153	**0.000400156**	0.000800312	100%
2	Project Areas Where Maintenance Associates Were Involved	0.002180305	**0.002420866**	0.004841731	100%
3	Project Areas Where Operating Associates Were Involved	0.00550252	**0.004005126**	0.008010251	100%
4	Project Goals Which Were Considered Absolutely Fixed	0.001754525	**0.005712277**	0.011424554	99%
5	Degree of Project Manager Empowerment	0.062771963	**0.006674532**	0.013349063	99%
6	Project Team Structure And Location	0.0181818	**0.010355694**	0.020711387	99%
7	Degree Of Goal Definition Prior To Project Approval And Launch	0.069352061	**0.011101952**	0.022203904	99%
8	Amount of Owner In-house Engineering Expertise	0.059507392	**0.024867782**	0.049735563	98%
9	Degree of Scope, Budget, And Schedule Definition	0.146784679	**0.025466625**	0.050933249	97%
10	Use of Performance Incentives	0.022293586	0.017632602	**0.035265203**	96%
11	Level Of Project Executive Sponsor	0.098169176	**0.043180593**	0.086361186	96%
12	Amount of Strategic Analysis Used To Develop Project	0.031721995	**0.055717144**	0.111434288	94%
13	Risk Management Techniques Which Were Employed On Project	0.115551021	**0.079964246**	0.159928491	92%
14	Source of Design and Engineering Services for the Project	0.357129541	0.067897213	**0.135794425**	86%
15	Level of Process Control and Automation Systems Involved in Project	0.20698309	0.084510102	**0.169020203**	83%
16	Use of Fixed Price Contracts	0.363022454	0.136035233	**0.272070466**	73%
17	Level Of Detail Used In Engineering Drawings	0.281662995	0.14076846	**0.28153692**	72%
18	Was Project Manager To Ultimately Manage The New Facility	0.283654224	0.173296754	**0.346593507**	65%
19	Level of Detail Used By Owner In Design and Purchase Specifications	0.675496816	0.297132008	**0.594264016**	41%
20	Who Established Goals and Degree of Challenge For The Project	0.788921521	0.343766404	**0.687532808**	31%
21	Use of Time & Materials Contracts	0.792682366	0.39117764	**0.782355279**	22%
22	Use of Turn-key Contracts	1	0.5	**1.000000**	0%
23	Amount of External Customer Involvement Throughout Project	1	0.5	1.000000	0%

1. Project Manager Background and Skills

The background and skills of the Project Managers leading successful projects, were much broader than for those leading unsuccessful projects. (Confidence Level: 100%)

Virtually all of the project managers leading projects included in this research had an engineering background. However the breadth of experience beyond their education differed significantly. The backgrounds ranged from narrow specialists such as an electrical design engineer (having always worked as a design specialist), to engineers having exposure to manufacturing, marketing, or project management, to the extreme of having a broad combination of all of these experiences and skills. Project managers associated with successful projects typically possessed a much broader background, while those associated with the failed projects had a much more narrow specialty background. Through follow-up discussions it was learned that these narrow specialists were very experienced and highly qualified professionals, but had spent their careers in narrow engineering specialties. Clearly these narrowed focused specialists are invaluable to the design process, but the breadth of experience at the Project Manager level appears to pay big dividends in terms of project success.

Discussions with major engineering companies indicated that a disproportionate number of their project managers have mechanical and civil engineering backgrounds. The view was that these disciplines have a broader application and provide an excellent foundation to prepare a project manager to be conversant with a number of other fields. In addition, there were several examples of successful project managers who had a technical degree other than engineering, although the clear advantage falls to the engineering graduate. The qualifications for a successful Project Manager is preferably an engineering degree, but with further broadening beyond the classical engineering education. For this reason, the qualifications required by the Project Management Institute when testing and certifying professional project managers include both educational background (e.g. engineering) and project related work experience.

In larger engineering companies the typical path for project manager development after completing an engineering degree is;

Design Engineer (from year 1 - 5)

Lead Design Engineer (from year 6 - 10)

Project Engineer (from year 11 - 13)

Project Manager (beyond year 13)

2. Project Areas Where Maintenance Associates Were Involved

Key maintenance associates had significantly more early involvement with the successful projects than with the unsuccessful projects. (Confidence Level: 100%)

The importance of involving the end user is a well established truism, one which is routinely practiced in software engineering and other design activities. The survey research clearly indicates how strongly the involvement of key maintenance associates correlates with project success. 100% of the successful projects extensively involved key maintenance personnel early in the project, well ahead of startup. Less than half of the unsuccessful projects involved these key associates prior to debugging and start up, and only one-third even included them in design reviews. In both successful and unsuccessful projects, involvement in the early project stages was more limited compared to the final training, installation, and equipment debugging. With such a strong influence on project success, it is surprising to see two thirds of the unsuccessful projects failed to involve key maintenance associates. The author has observed that this early involvement provides valuable input to improve the selection and design of the process equipment, but perhaps even more importantly builds competency and commitment in the maintenance associates. While this involvement is an expense during the project, it is invaluable in preparing those associates who will ultimately care for the process equipment.

Perhaps a relevant questions to ask is, "If early involvement of key maintenance associates is so important, why is it overlooked so often?" This research suggests that this is typically an act of omission, rather than one of commission. Managers indicate that short term cost and time pressures interfere with freeing up key maintenance associates to allow appropriate involvement. Another common mistake is to assign someone to "get involved" with the project, but not relieving them of any of their current responsibilities. There is also a dilemma that full time involvement of these associates is not required throughout the project, however sporadic involvement can be very disruptive to the design process. A recommendation by many was that specific tasks and project responsibilities should be assigned to these part-time maintenance associates, such as development of preventative maintenance procedures, design review, etc. While these tasks may only require a part-time commitment, their role in the project would formally defined and they will be accountable for specific deliverables. With major new installations, it is necessary to design a "new" maintenance organization to startup along with the new equipment and operating team.

3. Project Areas Where Operating Associates Were Involved

Key operating associates had significantly more early involvement with the successful projects than with the unsuccessful projects. (Confidence Level: 100%)

As in the case of maintenance associates, involvement of key operating associates appears to be a key determinate of project success. Here as well, 100% of the successful projects extensively involved key operating associates early in the project, compare to less than 50% of the unsuccessful projects. The selection and development of these operating associates long before equipment installation is essential. The more involvement in the project that these associates have, the higher the level of commitment will be. Where possible this should include involvement with equipment selection design reviews, developing operating procedures, and training, and even non-traditional areas such as helping to install equipment, selecting paint schemes...anything to help build ownership. This operator development should not be limited to technical training, but rather should include education about the business and exposure to more competitive operating cultures. On several projects, large operating teams were sent to suppliers throughout the world at a considerable expense, to expose them to the best operating systems. They returned from this training with new technical skills, accompanied by even more valuable cultural awareness and new work attitudes.

4. Project Goals Which Were Considered Absolutely Fixed

Project goals such as schedule, cost, scope, and product were more frequently considered absolutely fixed for successful projects than for unsuccessful projects. (Confidence Level: 99%)

Considering project goals such as schedule, cost, scope, and product quality to be absolutely fixed, was significantly more prevalent in successful projects. The current literature, in particular in the software engineering industry cautions against this practice, claiming that it will lead to poor quality and unusable designs. It is true that on a project containing high technical complexity such as a research project, it is more difficult to develop firm estimates. The author does however strongly believe that developing realistic, achievable goals, and then considering them absolutely non-negotiable leads to project success far more often than failure. These goals and deliverables help the project team set priorities and provides a license to secure other needed resources. Developing a positive mindset that these goals are commitments, not just targets, creates an "action-orientation" in the project which is essential to planning the needed activities and working to accomplish the plan. Viewing key milestones and endpoints in this way encourages early planning and recognition of critical path activities. Risk management and contingency planning also play important role in anticipating project goals at risk and in developing effective countermeasures.

5. Degree of Project Manager Empowerment

The degree of project manager empowerment was higher for successful projects than for unsuccessful projects. (Confidence Level: 99%)

All project managers leading successful projects were either significantly or fully empowered, where-as 44% of the unsuccessful projects were managed by a project manager with minimal empowerment. The research pointed to several causes for the lack of empowering project managers and the problems which result. It is not likely that any project manager was assigned and intentionally not empowered. This is typically a situation which evolves during the course of the project.

A frequently cited reason for the lack of project manager empowerment was excessive involvement of senior management in the details of the project. A trend was cited in the steel industry which is making this phenomena more prevalent. The economic pressures of the last two decades and the emergence of smaller companies, have led to fewer major capital projects. Since each project is now considered critical to the success of these companies, they are highly visible to senior management. A follow-up interview with one senior manager to discuss reasons for a failed project at his company revealed an interesting perspective on empowerment. In his opinion, he had fully empowered his project manager, but due to the project manager's personal limitations this empowerment was not accepted. This senior manager felt quite justified in stepping in routinely to make detailed project decisions to keep the project on track. As you can see, this phenomena can result in a death spiral. As the senior manager continued to intervene on project decisions, he further eroded the project manager's effectiveness. This cycle must be avoided by careful selection of a qualified project manager early in the inception of the project, and by developing a clear understanding the respective roles of the project manager and executive sponsor.

The consequences of inadequate project manager empowerment are dire. The project manager must provide leadership to the project, and is a key point of integration. If the project manager's authority is undermined, these two critical roles will not be fulfilled.

6. Project Team Structure And Location

Projects utilizing full time co-located project teams were more successful than projects utilizing part time project support staffs. (Confidence Level: 99%)

The type of project team structure and location showed a strong correlation with project success. Nearly 90% of the successful projects operated with full time staffs, and in nearly half of the time had full time support personnel co-located with the project team. Conversely two-thirds of the unsuccessful projects were managed by a part time staff, in spite of their large size.

Full time co-located teams provide key benefits with respect to alignment and communications.

Alignment

It is much easier to ensure the focus of the project team when they are committed full time and preferably co-located. One of the most important roles of the project manager and executive sponsor is to align the team on achieving the goals of the project. The project team structure and location and help develop esprit d'corp and a winning attitude.

Communication

The proximity of key project personnel can greatly aid the communication, which is always critical to the success of a project. In particular informal communication is facilitated with a co-located team. The importance of this type of communication changes throughout the course of the project. During the early conceptual development phase of a project this intimate contact and "continuous" communication is most important. Later in the design phase, the project can and actually should move to a more structured form of communication to avoid frequent or late design changes arising from casual discussion. In spite of this risk of late design changes, the author's view is that close proximity of key project personnel is always preferable.

7. Degree Of Goal Definition Prior To Project Approval And Launch

Projects having clearly defined goals and measurable deliverables prior to approval and launch were more successful than those projects having a less defined set of goals. (Confidence Level: 99%)

The degree to which goals were defined prior to approval and launch strongly correlated to project success. For nearly 90% of the successful projects, firm, measurable deadlines and deliverables were developed prior to launch. This compares to only one third of the unsuccessful projects. Projects which do not have clearly defined goals will not likely produce desirable objectives, except through serendipity. The organization of the project phases should account for an appropriate goal definition phase.

There is an important distinction between Project "Management" and Project "Leadership" which is relevant to establishing project goals.[1] Individual milestones and deliverables are important to "managing" a project to accomplish its objectives on schedule and on budget. Developing a vision for the project and aligning the project team and organization around that vision is "Leadership". Some projects have a natural "overarching" goal which serves to motivate and align the team, while others must be defined and communicated by the project "leader". This point of an overarching or "superordinate" goal can be illustrated by considering some of the greatest examples of craftsmanship, the building of the great cathedrals in Europe. Dr. Wayne Brockbank uses the example of the craftsman building the front door of a great European cathedral.[2] When asked what he is doing, the craftsman might reply, "Why can't you see I am building or a door; Or he might reply, "I am building a cathedral so that people can come here and worship for centuries to come." Frederick Brooks in The Mythical Man-Month also uses a Cathedral analogy, this time the Reims Cathedral, to illustrate the importance of an overarching goal.[3] Even though eight generations of master builders spanning several centuries were used to create the present design, the end product achieved conceptual integrity. In both of these examples, the clear and important superordinate goal of "Building a Cathedral" helped to motivate and align the "project teams", from the individual craftsman building the front door to the very influential master builders. Rockwell International cited the "creation of a superordinate goal" as a key success factor in their fixed price project to build 100 B1-B bombers for the U.S. Air Force.[4]

8. Amount of Owner In-house Engineering Expertise

The level of in-house engineering expertise was significantly higher for successful projects than that available to unsuccessful projects. (Confidence Level: 98%)

The amount of engineering and technical expertise which the owner (steel company) had during the project correlated strongly to the success of the project. Nearly one-half of the successful projects were conducted in an environment where the owner company was viewed as having in-house engineering expertise well above the industry average. Conversely none of the unsuccessful projects were conducted in the same above average engineering environment. In fact nearly one-half of the unsuccessful projects were carried out where the owner company had minimal in-house expertise. Since all of the these projects were large in scope, virtually none of them were conducted using in-house engineering alone. The main benefits of the in-house engineering expertise were in the early development of the project and the interaction with suppliers on process technology, engineering, equipment, and systems issues. This interaction began with the development of functional specifications, supplier selection, design reviews, equipment startup, and acceptance. While the in-house engineering staff was not designing the equipment, they were in a position to make appropriate recommendations to ensure the desired functionality. They also provided a valuable engineering resource during equipment installation, debugging, and startup.

9. Degree of Scope, Budget, And Schedule Definition

The degree of project scope, budget, and schedule definition prior to final approval and launch was significantly higher for successful projects than for unsuccessful projects. (Confidence Level: 97%)

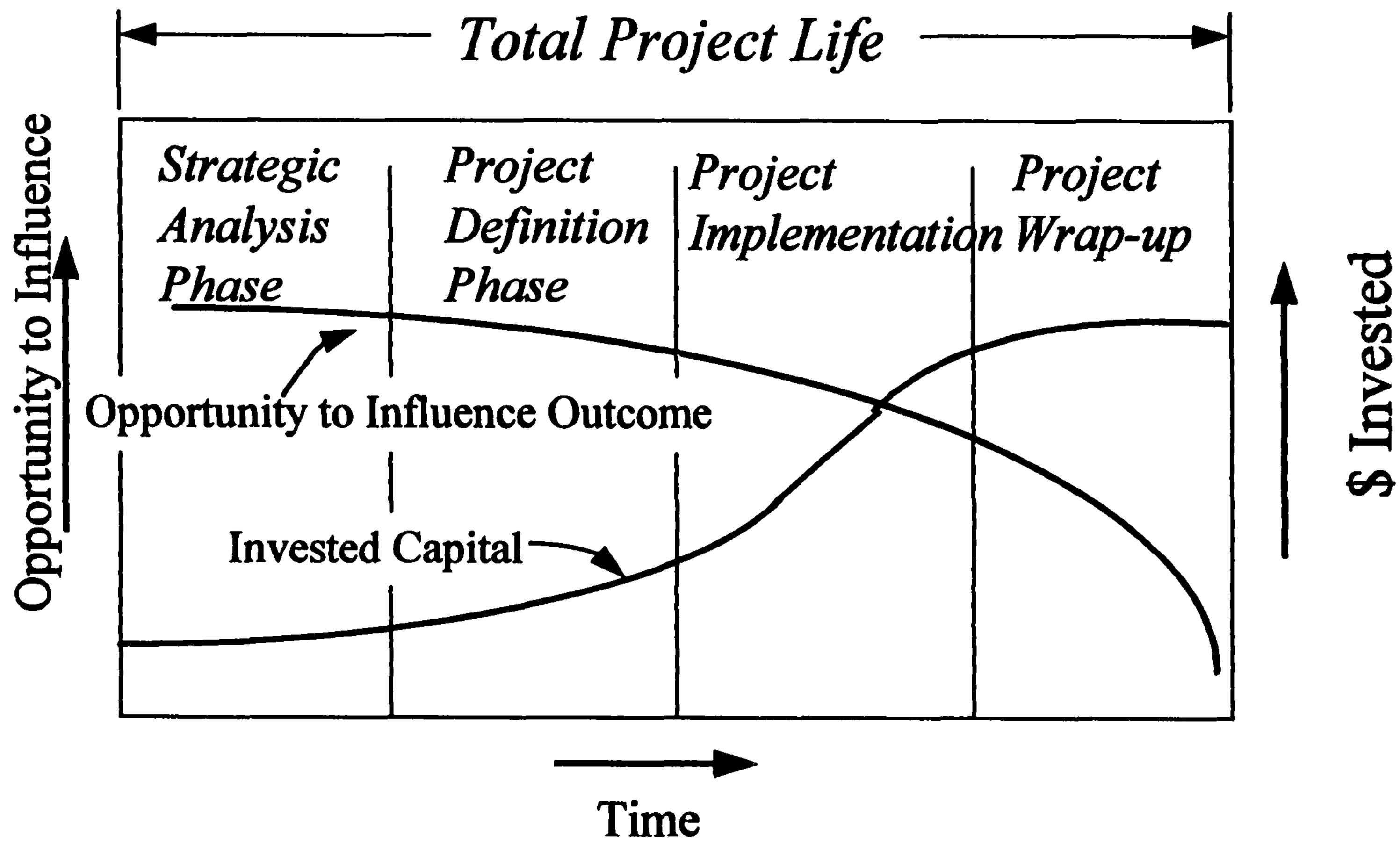
The degree of scope, budget, and schedule definition prior to final project approval and launch correlated strongly to project success. Nearly 90% of the successful projects had good or firm scope, budget, schedule estimates prior to launching. On the other hand nearly one-half of the unsuccessful projects had minimal scope, budget, and schedule definition when launching the project.

There are several approaches which have been recommended by various authors to complete the Preliminary Project Engineering or Project Definition.[5,6] The author's experience is that this is the most important phase of the project and should not be shortchanged. Saving a month of up-front planning may end up creating a one year delay later in the project.

If you examine the risk profile for a project in Figure 6.1, you also see that during the early project definition phase, the greatest opportunity exists to influence the outcome of the project and when there is the least amount of capital committed.[7] By the end of this project definition phase, less than 5% of the project budget has been expended.[8] As the project progresses into the design and build phases, the capital invested grows exponentially and the cost of design changes increases dramatically. The author has observed that the time necessary to develop quality estimates and realistic milestones is time very will spent. As the project then moves into implementation, the pace should be as brisk as possible.

Project Scope and Investment Curve

Figure 6.1



10. Use of Performance Incentives

Supplier performance incentives were more frequently used in successful projects than for unsuccessful projects. (Confidence Level: 96%)

The use of positive reinforcement through performance incentives was found to be much more prevalent in successful projects. Nearly half of the successful projects used some form of performance incentives in the form of a supplier bonus, whereas none of the unsuccessful projects used supplier incentives. With over one half of the successful projects being completed without the use of incentives, their use should clearly not be considered a critical success factor. However, performance incentives are rapidly becoming more prevalent as the industry moves towards more partnering arrangements with suppliers. In these arrangements, suppliers are being asked to reduce their costs and absorb some additional business risks and costs. The expectation is that these suppliers will likewise share in the rewards for superior performance. While establishing fair measures and performance criteria can be difficult, such incentives ensure that suppliers are aligned with the business needs of their client.

The use of negative reinforcement in the form of performance guarantees and penalties has been prevalent in the industry for an even longer period of time. In this survey, 66% of the successful projects and 55% of the unsuccessful projects used performance guarantees. A common theme however was that regardless of how performance guarantees are written, the client company still bears the ultimate responsibility for the project success. The importance of selecting qualified suppliers is clearly the most important method of influencing performance. Careful assessment of supplier capabilities, experience, references from past jobs, and financial solvency should be considered mandatory prior to entering into a purchase agreement. No level of performance incentive or penalty can offset the problems encountered with a supplier who is lacking the skill or financial solvency to perform their work. Once a qualified supplier list is developed however, the creative use of incentives should be considered as a method of encouraging superior performance.

11. Level Of Project Executive Sponsor

The level of executive sponsoring successful projects was significantly higher than the level sponsoring unsuccessful projects. (Confidence Level: 96%)

Each project included in this analysis had some form of executive sponsor. This role was filled by a Vice President or above 85% of the time. The average level of executive sponsoring the successful project was significantly higher than the average for the unsuccessful project, to a 96% confidence interval. The primary roles of the sponsor are to help establish the higher level goals for the project, lend personal endorsement to the project, ensure availability of necessary resources, and to monitor progress against the higher level project goals. The role is not intended to involve daily activity with the project, and in fact that level of involvement was cited as being detrimental to several of the surveyed projects. The reason that successful projects tended to have higher level sponsors can likely be explained when examining the roles stated earlier. The business-wide vision, influence, and authority tends to increase with higher levels in the business organization. Each of these attributes increase the sponsors effectiveness in fulfilling their respective role.

12. Amount of Strategic Analysis Used To Develop Project

The amount of strategic analysis used to develop successful projects was significantly greater than the amount used for unsuccessful projects. (Confidence Level: 94%)

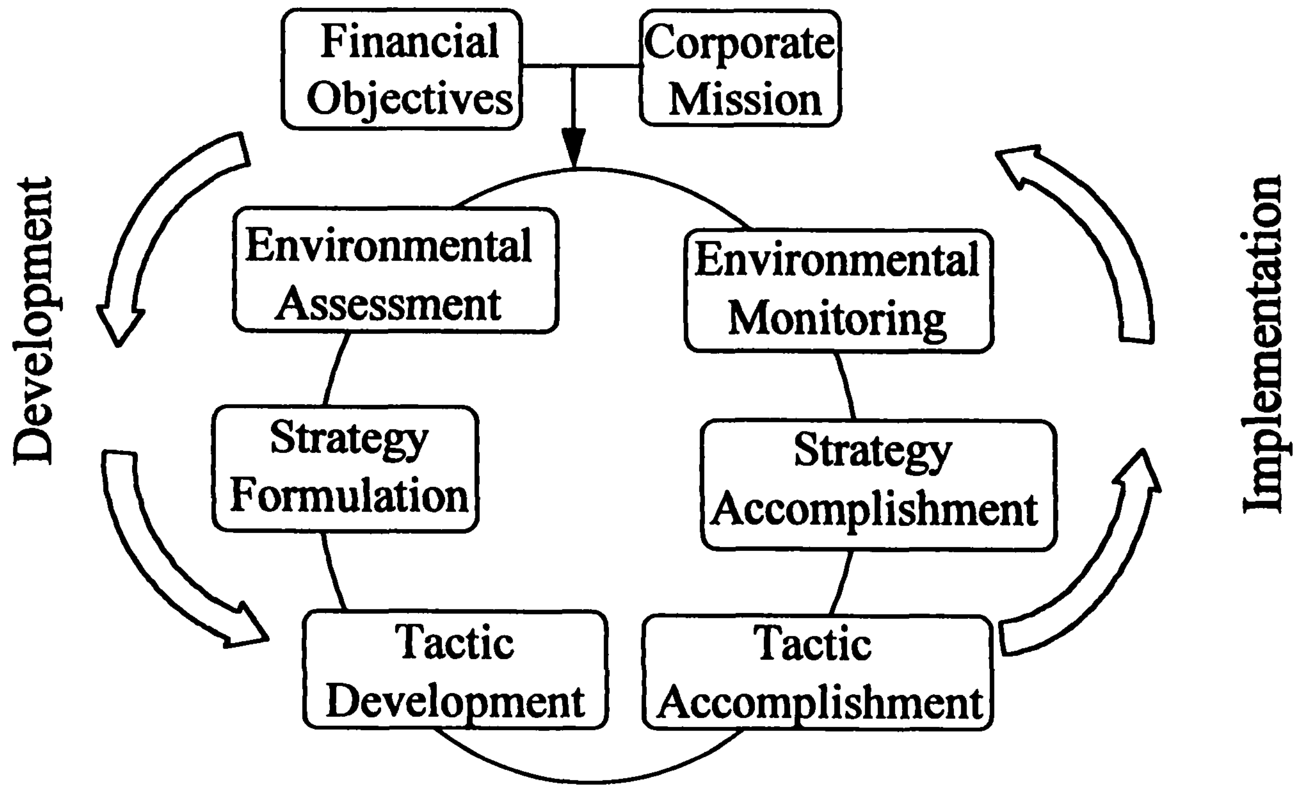
All of the successful projects were cited as having thorough if not an excessive amount of strategic analysis prior to their start. One-third of the unsuccessful projects had only a minimal amount of strategic analysis. This strategic analysis is more a determinant of project effectiveness as compared to project efficiency. Some of the projects included in this research accomplished exactly what was being asked for, but were considered a failure because they were fatally flawed during the planning phase. Perhaps even more important is the "quality" of the strategic analysis and not the amount of analysis. Making direct comparisons of the quality of analysis from company to company is extremely difficult.

Strategic Planning

The origins of formal strategic planning can be readily traced to military applications. It was first applied in industry in the mid-1970's as large companies were finding that some products were not yielding profits and they were losing focus on their core businesses. In an attempt to decide where they should focus their attention, these large companies were looking for a selection process. The strategic management process was transferred to industry from the operations research field, which included an internal assessment of strengths and weaknesses, and an externally based assessment of opportunities and threats. This process ensures that external benchmarking and customer needs assessment supplements the more traditional internally driven planning process for capacity expansion and investment projects. Figure 6.2 illustrates the strategic management process used at The Timken Company.[9] This process starts with the Corporate Mission and Financial Objectives. The strategy development phase illustrated on the left side of the figure includes environmental assessment (external threats and opportunities, internal strengths and weaknesses), strategy formulation (what we would like to accomplish), followed by tactic development (how we will accomplish the strategy). The strategy implementation phase is shown on the right side of the figure. Tactic accomplishment typically would involve a specific project or series of projects. Strategy accomplish would follow, and finally environmental monitoring would complete the cycle.

The Strategic Management Cycle

Figure 6.2



Source: The Timken Company

13. Risk Management Techniques Which Were Employed On Project

The amount of risk management employed on successful projects was higher than that employed on unsuccessful projects. (Confidence Level: 92%)

It was interesting to learn that none of the unsuccessful projects used any form of formal risk analysis or contingency planning, and used prototyping benchmarking, simulation far less often than the successful projects. The unsuccessful projects did however, use performance guarantees nearly as often as the successful projects. This may imply an over reliance on the supplier for ensuring the success of the project, and not sufficient prospective analysis and planning on the client's part. "Project Management is the art and science of indentifying, assessing, and responding to project risk throughout the life of a project and in the best interests of its objectives." [10]

Spectrum of Responses to Risk During A Project

- Unrecognized, unmanaged or ignored (by default)
- Recognized but no action taken (absorbed as a matter of policy)

⇒ Avoided (by taking appropriate steps)

⇒ Reduced (by an alternative approach)

⇒ Shared (with others, e.g. by joint venture)

- Transferred (to others through contract or insurance)
- Retained and absorbed (by prudent allowances)

Note: (or handled by a combination of the above.)

The consequences to such responses to risk are illustrated in Table 6.2.

Table 6.2 Response To Risk And Consequences

Response to Risk	Consequence
Unrecognized, unmanaged, or ignored (by default)	Reliance on luck (good or bad), no knowledge gained. No opportunity to mitigate impact.
Recognized but no action taken (absorbed as a matter of policy)	Provides awareness of risk but may still lead to failure to meet project objectives.
Avoided (by taking appropriate steps)	Effective as long as conservatism is not the universal method used to avoid the risk.
Reduced (by an alternative approach)	Effective if alternative approach does not compromise project objectives.
Shared (with others, e.g. by joint venture)	Effective if partner is trustworthy and in position to help avoid, reduce, or absorb impact of risk.
Transferred (to others through contract or insurance)	Expensive and often ineffective.
Retained and absorbed (by prudent allowances)	Requires contingency allowance in budget, which once provided is always used, leading to increased project costs.

Risk is often the result of having to make decisions in the presence of uncertainty and inadequate information. As the project progresses the uncertainty diminishes and complete information is available. However certain decisions can not be delayed until complete information is available, without creating other forms of risk i.e., schedule slippage, cost overruns, etc.

One recent trend which is impacting risk management is the development of better computer simulation tools. Higher level simulation software e.g. SLAM, Siman, Factor, are easier to develop and have improved post-processors which make interpreting results much easier. This permits one to "build" the process ahead of time and run it through numerous iterations to study material flow, process constraints, and other design limitations. The development of low cost, high speed personal computers and micro-work stations have increased the rate of running these iterations. Once built these simulations can be combined with experimental design concepts to run multi-variable factorial experiments. The results can then be plotted in graphical form such as contour plots, making interpretation and presentation to project personnel much easier.

Prototyping is another method of risk avoidance or risk minimization. For critical process areas prototyping should be considered. Innovation and creativity is often required to find methods to prototype the process with the constraints of time and budget. However, the knowledge learned by prototyping can not only avoid expensive mistakes, but often leads to opportunities to improve or reduce the design costs, and can speed up the project in later phases.

Modeling (Physical or Computer) are both effective tools in prototyping a process. Finite element tools and the increased performance micro-computer work stations have advanced this capability and shifted the cost/benefit ratio downward.

14. Source of Design and Engineering Services for the Project

There was no strong correlation between the source of engineering services and project success, however unsuccessful projects tended to rely more heavily upon equipment suppliers and major outside engineering firms for their engineering services. (Confidence Level: 86%)

As steel companies underwent restructuring in the 1980's and 1990's, the large internal engineering departments began to shrink and more engineering services were purchased from external sources. External sources were either large full service engineering and construction firms, or smaller local design houses. The size of external sources used typically correlated with project size. When considering that the average size for the successful projects was $83 million verses an average of $51.4 for the unsuccessful projects, it is surprising to see the trend of less successful projects relying on large external engineering sources.

15. Level of Process Control and Automation Systems Involved in Project

There was no strong correlation between level of process control and automation on project success, however successful projects tended to incorporate higher levels of automation. (Confidence Level: 83%)

This lack of distinction for the level of automation may be the result of offsetting factors. Clearly, the comments provided in the survey indicated significant managerial complications and risk with higher levels of automation. However, most strategically important new facilities incorporate higher levels of automation and receive significant benefits. However, automation likely warrants more rigorous project management and scope control than any other area.

17. Level Of Detail Used In Engineering Drawings

There was no strong correlation between the level of detail used in engineering drawings and project success, although there appeared to be a slight trend towards successful projects using more detail. (Confidence Level: 72%)

There is an industry trend toward the use of minimal engineering. This approach is used extensively by Nucor, who has developed an image in the steel industry of being fast, innovative and getting to market first. The traditional concern which is raised regarding minimal engineering is that errors will be made during fabrication or field installation. This risk clearly exists, however companies like Nucor have elected to assume this risk in order to accelerate their projects. Another strategy often used is to compensate for minimal detailed engineering by using extra field engineers to work out difficulties as they arise.

A frequent response observed in this research was that it is not the level of detail or quantity of engineering drawings which was critical, but rather the quality of the engineering drawings. This may imply that if the quality of the engineering supplier is sufficient, that minimal engineering can work effectively.

It is clearly evident that when limited detail is available to complete a fabrication or installation, risk is present. As long as this risk is determined to be justified based upon project schedule or real cost saving, then minimal engineering may be considered. Companies should be extremely careful in the author's view, to avoid developing a laissez-faire attitude towards engineering completeness and accuracy.

The following Table 6.3 is an attempt to define those project which are well suited for the application of minimal engineering verses those projects where minimal engineering may not be appropriate.

Table 6.3

Projects Supporting Minimal Engineering	Projects Not Suited For Minimal Engineering
Retrofit project	Greenfield project
Parties Willing to Share Risk	Shutdown projects with high risk of interfering with existing operations.
Composition of Project Team (e.g. early involvement of construction engineer and contractors)	Critical window of opportunity where any field delays can not be tolerated.
Less Complex Projects	Safety critical project
Later generation of design (2nd, 3rd, 4th)	
Experience level of contractor with technology being used.	

18. Was Project Manager To Ultimately Manage The New Facility

There was no strong correlation observed between the use of a project manager who was destined to operate the new facility and project success. (Confidence Level: 65%)

There are those who believe that the project managers assigned to lead major projects should be the individual who ultimately will have the responsibility to manager the facility. The concept is that this should provide the ultimate in continuity, competence, and commitment to making the operation a success. The data does not however show this to be a major trend nor any apparent influence on project success.

In follow-up discussions on this subject, most respondents agree that ideally this approach would provide the above described benefits. They have in practice however, found it very difficult to find people who have the skill, experience, and interest in performing both functions very well. Many of the disciplines and methodologies used in project management differ from those used in managing an ongoing operation. In the absence of these double-vested project managers, many companies are successfully pairing up two individuals who possess these complimentary talents. One person must take the lead role for conflict resolution, however there should be reasonable balance in their influence on key project decisions.

This can also be effective as the project evolves through various phases. Early on the operational manager can take the lead in defining the process and assessing equipment suppliers, in essence defining what will be purchased and installed. In the later design and build phases, he can then turn his attention towards operating organization and startup issues while the engineering manager takes the lead in working with the suppliers on design details.

19. Level of Detail Used By Owner In Design and Purchase Specifications

There was no correlation between design and purchase specification level of detail and project success. (Confidence Level: 41%)

There is one school of thought in industry which believes that you need very detailed specifications when purchasing equipment or design services. Volumes of detailed specifications and design standards were generated in the industry during the 1970's and 1980's. Steel companies typically had large central maintenance and engineering organizations who developed these specifications with the intention of ensuring equipment reliability and ease of maintenance. Typically the bigger the steel company, the thicker the design specifications and standards. During the 1980's there emerged another school of thought driven heavily by the mini-mills that these design standards added unnecessary cost to project administration and equipment purchases. The other extreme of taking anything off-the-shelf with no as-purchased specification was often used.

The authors interpretation of these results is that this data represents a mixture of two distinct phenomena. Detailed specifications which spell out the type and brand of every nut and bolt on the project can be very detrimental. Suppliers have no flexibility to provide innovative and superior design choices and their prices will reflect the cost of customizing their designs to meet your specifications. On other hand a clear well written functional specification can be enormously important to the success of a project. Here the operational performance parameters are clearly defined but latitude is made available to the suppliers on how this performance can best be achieved. Often times in the past, design and purchase specifications were voluminous but contained very little information on the most important performance expectations for the process or equipment.

20. Who Established Goals and Degree of Challenge For The Project

Project goals and degree of challenge were more frequently set at senior manager levels however, there was no correlation between who established the goals and degree of challenge and the success of a project. (Confidence Level: 31%)

There are views held by some that unless the project manager or team set the goals for the project, they will not be totally committed to their achievement. There are others who believe that if given the opportunity to set their own goals, a project team may be too conservative and not stretch far enough in establishing project goals. These views may explain why this data revealed no difference as a function of who set the goals. The issue of establishing appropriate goals is a matter of leadership. At the outset of a project there is a great deal of uncertainty regarding the future. Strong leadership will assess the situation at that point and develop a vision of what can and should be accomplished. This vision will then be communicated in the form of project goals. The presence of this leadership is without question critical to the success of any project. Who specifically in the organization fills that role is of less importance. At times it may come directly from the top of an organization, or from a steering committee, or it may emanate directly from the project manager or project team itself. This may be the reason that the specific level of person who set the project goals did not correlate well with the degree of project success.

16. Use of Fixed Price Contracts

There was no strong correlation between the general use of fixed price contracts and project success, however successful projects made a greater use of fixed price contracts for engineering and equipment installation. (Confidence Level: 73%)

Fixed price contracts were found to be the predominant means of purchasing equipment, often used for installation contracts as well, and seldom used for engineering services. Fixed price contracts are attractive to a client in that they theoretically cap the cost of the contract and keep the responsibility for cost control with the supplier. Companies with weak balance sheets often have to resort to fixed price or even turn-key contracts in order to secure financing for their projects. When the use of fixed price contract begin to lead to difficulties is when there is a high degree of uncertainty with the project and scope changes are likely to occur.

21. Use of Time & Materials Contracts

There was no correlation between the use of time and material contracts and the level of project success. (Confidence Level: 22%)

Time and material contracts are frequently used as a means of purchasing engineering and installation services. They are much less frequently used when purchasing equipment, with the exception of one-of-a-kind prototypes. There are some beliefs that the use of time and materials contracts should be kept to an absolute minimum in order to avoid cost overruns. There are others that view them as an extension of partnering which allows projects to proceed more quickly by avoiding a lengthy bidding process. Suppliers are more often the advocate of this approach claiming that a less confrontational relationship exists and the quality and cost of the project is improved. This approach relies heavily on the trust which the client has in the given suppliers. The level of uncertainty at the outset of a project and availability of qualified suppliers has a significant influence on where time and material should be considered verses fixed price or even turn-key supply contracts.

22. Use of Turn-key Contracts

There was no correlation between the use of turn-key contracts and the level of project success. (Confidence Level: 0%)

The use of turn-key contracts developed in the late 1970's and 1980's and have been used by both large steel companies and mini-mills. The theory is that by placing a contract with one company or consortium to supply the entire scope for the project, a single point of responsibility is ensured. In such contracts the owner has relatively little involvement with the project after placing the order, until it is time to operate the facility. Typically because of the magnitude of such contracts, fierce bidding occurs up front presumably leading to lower costs. The danger cited with a true turn-key contract is that the owner gets exactly what the contract stated up front and no more than that. The owner has little influence over the scope of the project after that point should changes be required. Again the degree of scope uncertainty and availability of qualified suppliers should be taken into account when considering turn-key contracts.

The author has developed a classification matrix which illustrates the effect which up front scope definition and availability of qualified suppliers has on project contract strategy. This matrix is shown as Figure 6.3 and is followed by Figure 6.4 which lists factors influencing the degree of scope definition and supplier availability.

Project Contract Strategies

Figure 6.3

Degree of Scope Definition	Few	Many
Firm	**Time & Material,** with either; a.) Fixed Fee, or b.) % Mark-up	**Fixed Price,** with either; a.) Single Turn-key, or b.) Multiple lump sum contracts
Loose	**Partnering,** using; a.) preferred supplier, and b.) performance incentives	**Split Contracts** a.) Time & Material - Definition Phase b.) Fixed Price - Execution Phase

Number of Qualified and Desirable Suppliers

Some Factors Influencing Scope and Supplier Availability

Figure 6.4

Degree of Scope Definition:

- Prior Project Development
- Maturity of Technology Being Used
- Retrofit verses a Greenfield Site
- Business Climate/Competitor Stability

Number of Qualified and Desirable Suppliers:

- Uniqueness of Technology
- Project Size
- Global Location of Suppliers
- Supplier Interest Level in Project
- Economy

23. Amount of External Customer Involvement Throughout The Project

There was no correlation between the amount of external customer involvement and project success. (Confidence Level: 0%)

This was undoubtedly the most surprising result of this research. The need to be more customer-focused or customer-driven is a message spoken daily in industry. The fact that 78% of the successful projects in this survey had either no or minimal customer involvement was astonishing. In considering this data however, one must keep in mind that these customers are the "external" customers, who ultimately purchase the steel. "Internal" customers such as the plant receiving the facility, or the personnel who will operate of maintain the equipment are not included in this description. As a separate part of the survey, the critical nature of involving those internal customers was abundantly clear. Most of the companies interviewed relied on internal personnel in marketing, product development, or corporate planning to be the spokesman for the external customer, rather than having direct customer contact with the project team. This concept is foreign to the author however based on this data, it appears to be prevalent in the industry. Clearly the early conceptual phase of a project must include significant interaction with customers to ensure that the project will create real value for the end customer. Perhaps in some companies this conceptual work is not considered as being part of "the project" and therefore not captured in these data.

The other critical phase to involve external customers is the qualification of the new process during or just after startup. This qualification process can become the critical path for the facility ramp-up to full production. Early involvement of external customers will accelerate this process.

References - Chapter 6

[1] Kotter, J.P., "A Force For Change, How Leadership Differs From Management," The Free Press, 1990

[2] Brockbank, W., Seminar Notes, University of Michigan, 1994

[3] Brooks, F.P., "The Mythical Man-Month," Addison-Wesley

[4] Rockwell International, Internal Trip Report, 1990

[5] Wideman, R.M., "A Framework for Project and Program Management Integration," PMI, 1991

[6] Hatch, G.G., Noskiewicz, T.M. and Goode, J.D., "Top Management and Capital Spending Projects," TMS Paper No. A74-90, 1984

[7] IBID (5)

[8] IBID (6)

[9] Strategic Management - Internal Timken Document

[10] Wideman, R.M., "Project and Program Risk Management," Project Management Institute, 1992

Chapter 7

Conclusions and Recommendations

The North American Steel Industry is a capital intense industry which relies heavily on projects to implement new technology and improve manufacturing productivity. The last three decades have seen the North American Steel Industry change from enjoying unchallenged dominance to an industry fighting for survival. Fierce global competition now dictates that investments made in this industry be carried out with extreme efficiency and effectiveness.

A strong correlation with the postulated critical success factor framework was found when studying numerous successful and unsuccessful projects recently completed in the North American Steel Industry. In addition, retrospective analyses of four recent major projects at The Timken Company demonstrated further validation of the critical success factor framework. The factors included in the critical success factor framework were ranked based upon their strength of correlation with project success or failure. Thirteen of the twenty-three factors which were probed using the industry survey, were found to correlate to project success with a confidence level exceeding 90%. These factors ranked in descending order of significance were;

1. Project Manager Background and Skills
2. Project Areas Where Maintenance Associates Were Involved

3. Project Areas Where Operating Associates Were Involved
4. Project Goals Which Were Considered Absolutely Fixed
5. Degree of Project Manager Empowerment
6. Project Team Structure and Location
7. Degree of Goal Definition Prior to Project Approval and Launch
8. Amount of Owner In-house Engineering Expertise
9. Degree of Scope, Budget, and Schedule Definition
10. Use of Performance Incentives
11. Level of Project Sponsor
12. Amount of Strategic Analysis Used to Develop Project
13. Risk Management Techniques Which Were Employed on Project

Several other factors showed a trend towards significance when related to project success. The confidence level in these factors being related to project success ranged from 86% down to 72%. Included in this category were;

14. Source of Design and Engineering Services for the Project
15. Level of Process Control and Automation Systems Involved in Project
16. Use of Fixed Price Contracts
17. Level of Detail Used in Engineering Drawings

There were 6 factors which while postulated as having significance to project success, were not supported by the data obtained through the external surveys. These factors included;

18. Whether the Project Manager Ultimately Managed the New Facility
19. Level of Detail Used by Owner in design and Purchase Specifications
20. Who Established Goals and Degree of Challenge For the Project
21. Use of Time & Materials Contracts
22. Use of Turn-key Contracts
23. Amount of "External" Customer Involvement Throughout The Project

Appropriate attention to critical success factors in developing competent engineers, project managers and project teams, and when implementing large strategic projects is recommended as a means of improving the probability of project success. The strength of correlation between the breadth of project manager experience and project success, points out certain implications for professional development. While the primary role of the university is to teach engineering fundamentals, opportunities for broadened project management exposure in the classroom or in an industry setting is likely of great benefit. The primary burden however, will likely continue to reside with the corporate world to ensure proper development of the future generation of project leaders.

Bibliography

Adams, J.R. and Campbell, B.W., "Roles and Responsibilities of the Project Manager," Project Management Institute, 1990

Anthony, R.N., Dearden, J., and Vancil, R.F., "Key economic variables, in Management Control Systems," Irwin, Homewood, Illinois (1972) pp. 138-143

Barker, J.A., "Discovering The Future," ILI Press, 1989

Barrie, D. S. and Paulson, B. C., "Professional Construction Management," McGraw-Hill, 1978

Bates, G.D., "Becoming an Effective Negotiator," Roenker Associates, 1991

Blanchard, F.L., "Engineering Project Management," Dekker, 1990

Block, R., "The Politics of Projects," Yourdon Press,

Box, G.E., Hunter, W.G., and Hunter, J. S., "Statistics for Experimenters," John Wiley & Sons, 1978, pp. 89,90

Brockbank, W., Seminar Notes, University of Michigan, 1994

Brooks, F.P., "The Mythical Man-Month," Addison-Wesley

Camp, R.C., "Benchmarking," Quality Press, 1989

Cleland, D.I. and Kerzner, H., "The Best Managed Projects," 1985 Proceedings from PMI Symposium, October 1985 pp. 1-24

Cooper, R.G., "Winning at New Products" Addison-Wesley 1994, pp. 75-94

Daniel, D.R., "Management Information Crisis," Harvard Business Review, Sept-Oct 1961, pp. 110-119

Fiechtner, S.B., "Improving Managerial Communication Skills," Communication Development Associates, 1991

Flanagan, J.C., "The Critical Incident Technique," American Institute of Research, University of Pittsburgh, July 1954

Francis, D., Young, D., "Improving Work Groups, A Practical Manual for Team Building," Pfeiffer, 1991

Hatch, G.G., Noskiewicz, T.M. and Goode, J.D., "Top Management and Capital Spending Projects," TMS Paper No. A74-90, 1984

Hayes, R.H., Wheelwright, S.C. and Clark, K.B., "Dynamic Manufacturing, Creating The Learning Organization," The Free Press, 1988

Hogan, S.J., William T., "Global Steel in the 1990's," Lexington Books, 1991

Hogan, S.J., William T., "Minimills and Integrated Mills," Lexington Books, 1987

Humphreys K.K., and English, L.M., "Project and Cost Engineers' Handbook," Marcel Dekker, 1993

Kerzner, H., "Project Management, A Systems Approach to Planning, Scheduling, and Controlling," Van Nostrand Reinhold, 1992

Kohrs, R. H., "The Impact of Flattening of the Corporate Organization - A New Role For Project Management", Project Management Proceedings, October 1993

Kotter, J.P., "A Force For Change, How Leadership Differs From Management," The Free Press, 1990

Leidecker, J.K. and Bruno, A.V. "Identifying and Using Critical Success Factors," University of Santa Clara, Long Range Planning, Vol. 17, No. 1, 1984, pp. 23-32

Lewins, K., "Frontiers in Group Dynamics" Human Relations, Vol. 1, No.1, 1947

Mager, R.F., "What Every Manager Should Know About Training," Lake, 1992

Marsh, P.D.V., "Contracting for Engineering and Construction Projects," Gower-Ashgate Publishing, 1988

Martin, D., "Teamthink," Dutton, 1993

Meyer, S.L., "Data Analysis for Scientists and Engineers," John Wiley & Sons, 1975 pp. 235-237

O'Brien, J. J., "CPM in Construction Management," McGraw-Hill, 1993

Peters, T.J. and Waterman, R.H., "In Search of Excellence, Lessons form America's Best-Run Companies," Warner Books 1982 pp. 11

Pinto, J.K. and Piscott, J.E., "Planning and Tactical Factors in the Project Implementation Process," Working Paper 89-07, University of Maine, Dec. 1988

Porter, M.E., "Competitive Advantage, Creating and Sustaining Superior Performance" The Free Press, 1985

Project Management Institute, Upper Darby, Pa.

Project Specifications and Standards - Internal Timken Documents

Rockart, J.F., "Chief Executives define their own data needs," Harvard Business Review, March-April (1979) pp. 81-92

Rockwell International, Internal Trip Report, 1990

Schaffer, R.H., "The Breakthrough Strategy," Ballinger, 1988

Shenhar, A.J. and Dvir, D., "Proceedings of the 28th Annual Hawaii IEEE International Conference on System Sciences," 1995, pp. 494-503

Shenhar, A. J., "Project Management In Modern Organizations", 1995

Strategic Management - Internal Timken Document

Thamhain, H.J., "Engineering Management," Wiley-Interscience, 1992

Webster, "Third New International Dictionary", 1961

Wellins, R.S., Byham, W.C. and Wilson, J.M., "Empowered Teams," Jossey - Bass Publishers, 1991

Whiteley, R.C., " The Customer Driven Company," Addison-Wesley, 1991

Wideman, R.M., "A Framework for Project and Program Management Integration," PMI, 1991

Wideman, R.M., "Project and Program Risk Management," Project Management Institute, 1992

APPENDIX A - Project Management Survey Form

Critical Factors Influencing Project Success - Assessment Exercise

To complete this portion of the survey, you will need to select two projects for analysis, using the following criteria;

A. The projects should be "strategic capital" projects, which to help clarify I will define as being *either*;

   ⇒ Large in terms of financial commitment (perhaps greater than $10-20 million).
   ⇒ Containing a significant amount of challenge or risk, (e.g., technical, commercial, organizational).
   ⇒ Requiring Senior Management or Board Level Approval.
   ⇒ Spanning several years from initial concept and business analysis, to completion and startup.

B. One of the selected projects should have been "Highly Successful" as defined by you. The second project should also have been carried through to completion, but having failed to meet significant performance, scope, budget, or schedule expectations, was considered "Unsuccessful" (or much less successful). The successful project will be referred to as Project "A", while the unsuccessful project will be called Project "C".

C. It is important for you to have direct knowledge of the projects. You need not have been directly on the teams managing the projects, but you must have a good understanding of the goals of the projects, the methods used to manage them, and their general outcomes. While your knowledge of the projects should be direct, you do not need to have precise details.

D. You need to be willing to discuss certain aspects of the projects in order to make this analysis complete and valid, (e.g. general objectives, sources of risk, project organization, general results). This would not of course need to include any confidential or competitive information. Any information provided will be treated with the strictest confidence. Individual names will not be disclosed and information will be discussed in aggregate form only. The information will not be used for any reason other than for the stated academic purposes.

Project Summary - Project "A" Highly Successful

Brief description of project, general objectives, date completed, approximate cost:

Reasons you consider this a "highly successful project":

In your opinion, what were the critical aspects of the way this project was developed, organized, engineered, and/or managed which made it successful.

Internal Organizational Structure for the Project "A"

a) On the next page, please sketch the internal organizational structure used for Project "A".

Ideally the sketch should include;

⇒ **The major groups (or individual positions) working full time on project (denote with a "F").**

⇒ **Other part-time groups (or individuals) having significant influence on the project (denote with "P").**

⇒ **The project executive sponsor, project manager(s), functional managers, project team, plant manager, operators, engineers, accounting, purchasing, etc.**

⇒ **Solid lines to indicate direct reporting relationships and dashed lines for indirect or matrix support.**

⇒ **Functional titles and an indication on the chart of who made what type and magnitude of decisions.**

⇒ **A perspective on how flat or tall the organizational hierarchical was.**

b) Please comment below, on the strengths and weaknesses of this internal organization and it's influence on the success of Project "A".

Please Sketch Below the (Internal) Organizational Structure for Project "A"

Contract Structure For the External Services and Equipment for Project "A"

a) On the next page, please sketch the contract structure for the external services and equipment for Project "A".

Ideally the sketch should include:

⇒ **The organizational relationship between the owner and general contractors, outside engineers, equipment suppliers, installation contractors, etc.**

⇒ **An indication of the contract type between the owner and the various outside companies. (e.g. Lump Sum Fixed Price, Lump Sum w/Bonus/Penalty, T&M w/% markup, T&M w/fixed fee, T&M with incentive award)**

b) Please comment below, on the strengths and weaknesses of this contract structure for the external services and equipment and it's influence on the success of Project "A"

<u>Please Sketch Below the Contract Structure For the External Services and Equipment in Project "A"</u>

I. The following questions are to help understand the role which upfront analysis, planning, and goal setting had on the outcome of Project "A":

Circle the amount of strategic (business case) analysis that went into the project before it was approved:
(Minimal, Thorough, Excessive).
How did this upfront analysis influence the outcome of the project?

____

____

____

Circle the degree of scope, budget, & schedule definition developed prior to project approval and launch:
(Minimal, Good ballpark estimates, Firm scope/budget/schedule)
How did this upfront planning influence the project success?

____

____

____

Circle how formal and firm the project goals were at the time the project was approved and launched.
(General objectives, Some quantified goals, Firm measureable deadlines/deliverables)
Did defining firm measurable goals up front increase their likelihood of achievement and the success of the project?

____

____

____

Circle who set the project goals (e.g. performance, schedule, budget) and their degree of stretch or challenge:
(Senior management, plant manager, project manager, functional managers, others)
How did this influence the project?

____

____

____

Circle any of the following techniques which were used to minimize or manage risk during the project:
(Formal risk analysis, Simulation, Prototyping, Benchmarking, Contingency planning, Performance Guarantees)
How did risk or risk management influence this project?

____

____

____

Circle any of the following project goals considered absolutely fixed and not subject to change by project team:
(Schedule, Installed Cost, Main Functionality, Product Quality)
Did this help or hurt the project, and why?

____

____

____

II. The following questions are to help understand how Project "A" was staffed and supported internally and how that affected it's outcome:

Circle the level of executive champion (i.e. sponsor, strong personal supporter) for the project:

(Chairman, President, VP, Plant Manager, Other, None)

In what way did that influence the project?

____

____

____

____

Circle any of the following backgrounds which would describe the lead project manager assigned to this project:

(Experienced P.M., Senior level, Specialized skills, Broad skills, Engineering, Manufacturing, Marketing, Finance)

How did his background help or hinder the project?

____

____

____

____

Circle the degree of empowerment the project manager had to make major decisions of scope, schedule, or budget?

(Minimal, Significant, Full)

How did this influence the outcome of the project?

____

____

____

____

Was the project manager the person who was to ultimately manage the new facility?

If so how did this influence the project?

____

____

____

____

Circle the best description of the project team structure used for this project:

(Part-timers, Full-time support located in functional departments, Full-time cross functional co-located team)

How did this project team structure help or hinder the project?

____

____

____

____

III. The following questions are to help understand how engineering was provided for Project "A" and how that influenced it's outcome:

Circle how detailed the specifications and standards were for purchasing engineering, equipment, buildings, etc:

(Minimal, Industry Average, Very detailed)

How did this affect the project quality, speed, cost?

Circle how detailed the engineering drawings were for equipment piping, electrical, foundations, etc.:

(Minimal, Industry Average, Very detailed)

How did this affect the project quality, rework, speed, cost?

Circle who provided the majority of the mechanical, electrical, piping, and civil engineering for the project:

(Internal staffs, Small local design firms, Major Engineering Companies, Equipment suppliers)

How did the source of engineering affect the project?

Circle the amount of in-house engineering expertise your company had during the time this project occurred:

(Minimal, Industry Average, Well above average)

In what way did that influence the project?

Circle the level of automation and process control systems which was used for this project:

(Level 1 PLC only, Level 2 DCS, Level 3 or higher plant wide sytems)

How was automation managed and how difficult was it to control it's scope, budget, or schedule?

IV. The following questions are to help understand the impact which involving customers, operators, maintainers had on Project "A":

Circle the amount of involvement which customers had in the project prior to startup:
(None, Minimal, Significant)
How did this affect the project?

Circle the areas of involvement which the operators had during the course of the project:
(Equipment selection, design review, develop operating procedures, training, installation, debugging)
How did this help the project?

Circle the areas of involvement which maintenance personnel had during the course of the project:
(Equipment selection, design review, develop maintenance procedures, training, installation, debugging)
How did this help the project?

Project Summary - Project "C" Unsuccessful (or less successful)

Brief description of project, general objectives, date completed, approximate cost:

Reasons you consider this an "Unsuccessful" or "much less successful project":

In your opinion, what were the critical aspects of the way this project was developed, organized, engineered, and/or managed which made it unsuccessful or less successful.

Internal Organizational Structure for the Project "C"

a) On the next page, please sketch the internal organizational structure used for Project "C".

Ideally the sketch should include;

⇒ **The major groups (or individual positions) working full time on project (denote with a "F").**

⇒ **Other part-time groups (or individuals) having significant influence on the project (denote with "P").**

⇒ **The project executive sponsor, project manager(s), functional managers, project team, plant manager, operators, engineers, accounting, purchasing, etc.**

⇒ **Solid lines to indicate direct reporting relationships and dashed lines for indirect or matrix support.**

⇒ **Functional titles and an indication on the chart of who made what type and magnitude of decisions.**

⇒ **A perspective on how flat or tall the organizational hierarchical was.**

b) Please comment below, on the strengths and weaknesses of this internal organization and it's influence on the success of Project "C".

<u>Please Sketch Below the (Internal) Organizational Structure for Project "C"</u>

Contract Structure For the External Services and Equipment for Project "C"

a) On the next page, please sketch the contract structure for the external services and equipment for Project "C".

Ideally the sketch should include:

⇒ **The organizational relationship between the owner and general contractors, outside engineers, equipment suppliers, installation contractors, etc.**

⇒ **An indication of the contract type between the owner and the various outside companies. (e.g. Lump Sum Fixed Price, Lump Sum w/Bonus/Penalty, T&M w/% markup, T&M w/fixed fee, T&M with incentive award)**

b) Please comment below, on the strengths and weaknesses of this contract structure for the external services and equipment and it's influence on the success of Project "C"

Please Sketch Below the Contract Structure For the External Services and Equipment in Project "C"

I. The following questions are to help understand the role which upfront analysis, planning, and goal setting had on the outcome of Project "C":

Circle the amount of strategic (business case) analysis that went into the project before it was approved:
(Minimal, Thorough, Excessive).
How did this upfront analysis influence the outcome of the project?

Circle the degree of scope, budget, & schedule definition developed prior to project approval and launch:
(Minimal, Good ballpark estimates, Firm scope/budget/schedule)
How did this upfront planning influence the project success?

Circle how formal and firm the project goals were at the time the project was approved and launched.
(General objectives, Some quantified goals, Firm measureable deadlines/deliverables)
Did defining firm measurable goals up front increase their likelihood of achievement and the success of the project?

Circle who set the project goals (e.g. performance, schedule, budget) and their degree of stretch or challenge:
(Senior management, plant manager, project manager, functional managers, others)
How did this influence the project?

Circle any of the following techniques which were used to minimize or manage risk during the project:
(Formal risk analysis, Simulation, Prototyping, Benchmarking, Contingency planning, Performance Guarantees)
How did risk or risk management influence this project?

Circle any of the following project goals considered absolutely fixed and not subject to change by project team:
(Schedule, Installed Cost, Main Functionality, Product Quality)
Did this help or hurt the project, and why?

II. The following questions are to help understand how Project "C" was staffed and supported internally and how that affected it's outcome:

Circle the level of executive champion (i.e. sponsor, strong personal supporter) for the project:
(Chairman, President, VP, Plant Manager, Other, None)
In what way did that influence the project?

Circle any of the following backgrounds which would describe the lead project manager assigned to this project:
(Experienced P.M., Senior level, Specialized skills, Broad skills, Engineering, Manufacturing, Marketing, Finance)
How did his background help or hinder the project?

Circle the degree of empowerment the project manager had to make major decisions of scope, schedule, or budget?
(Minimal, Significant, Full)
How did this influence the outcome of the project?

Was the project manager the person who was to ultimately manage the new facility?
If so how did this influence the project?

Circle the best description of the project team structure used for this project:
(Part-timers, Full-time support located in functional departments, Full-time cross functional co-located team)
How did this project team structure help or hinder the project?

III. The following questions are to help understand how engineering was provided for Project "C" and how that influenced it's outcome:

Circle how detailed the specifications and standards were for purchasing engineering, equipment, buildings,etc:

(Minimal, Industry Average,Very detailed)

How did this affect the project quality, speed, cost?

____

____

____

____

Circle how detailed the engineering drawings were for equipment piping, electrical, foundations, etc.:

(Minimal, Industry Average, Very detailed)

How did this affect the project quality, rework, speed, cost?

____

____

____

____

Circle who provided the majority of the mechanical, electrical, piping, and civil engineering for the project:

(Internal staffs, Small local design firms, Major Engineering Companies, Equipment suppliers)

How did the source of engineering affect the project?

____

____

____

____

Circle the amount of in-house engineering expertise your company had during the time this project occurred:

(Minimal, Industry Average, Well above average)

In what way did that influence the project?

____

____

____

____

Circle the level of automation and process control systems which was used for this project:

(Level 1 PLC only, Level 2 DCS, Level 3 or higher plant wide sytems)

How was automation managed and how difficult was it to control it's scope, budget, or schedule?

____

____

____

____

IV. The following questions are to help understand the impact which involving customers, operators, maintainers had on Project "C":

Circle the amount of involvement which customers had in the project prior to startup:

(None, Minimal, Significant)

How did this affect the project?

____

____

____

____

Circle the areas of involvement which the operators had during the course of the project:

(Equipment selection, design review, develop operating procedures, training, installation, debugging)

How did this help the project?

____

____

____

____

Circle the areas of involvement which maintenance personnel had during the course of the project:

(Equipment selection, design review, develop maintenance procedures, training, installation, debugging)

How did this help the project?

____

____

____

____

General Trends and Comments Section

Please describe any current or projected trends which are making it ***more challenging*** to successfully develop and manage large strategic projects in the steel industry:

Please describe any current or projected developments which are making it ***less challenging*** to successfully develop and manager large strategic projects in the steel industry:

Any ***additional comments*** of any type regarding Project Management which you would like to make:

Personal Background Information:

This information is requested to help quantify the collective experience base represented by the group of respondents to this survey. The information will be treated as confidential and will be viewed in aggregate, not associated with individual or company names.

I. Engineering Educational Background

Degree: *None Associate BS MS PhD (Circle one)*
Field: *Mechanical Civil Electrical Metallurgical Industrial Other*

II. Business Education Background

Degree: *BA MBA Advanced Management Development Programs(AMPs)*

III. Experience Profile

- *Years exerience in engineering profession (including management of engineers)*
  ________ *years*

- *Relative amount of direct experience as a Project Manager;*
  _____ *None - (Never served directly as a project manager)*
  _____ *Some - (Was project manager on a few projects)*
  _____ *Great deal of experience - (Frequently served as project manager)*

- *Approximate total cost of projects (TIC) which you have had some involvement with throughout your career; (check one)*

  _____ *< $10 Million*
  _____ *$10 to 50 Million*
  _____ *$50 to 100 Million*
  _____ *$100 to 200 Million*
  _____ *$200 to $500 Million*
  _____ *> $500 Million*