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ANALYSIS OF PROJECT MANAGEMENT ATTRIBUTES FOR THE SUCCESSFUL DELIVERY OF CAPITAL FACILITY PROJECTS

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by

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Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

May 2012

Dedication

This dissertation is dedicated to my wife, Youngyi, my daughter, Joowon, and my parents.

Acknowledgement

First, I wish to express sincere appreciation to my supervisors, Dr. Carlos H. Caldas and Dr. Stephen P. Mulva for their excellent guidance. This dissertation could not have been completed without their insights, comments, and encouragement. I also want to thank my committee members: Dr. Atila Novoselac, Dr. Christopher J. Jablonowski, and Dr. Fernanda Leite who gave me valuable advice throughout the development of this dissertation.

Second, I would like to thank my colleagues at work, both at the Construction Industry Institute (CII) and at the CEPM program. Many thanks must go to the CII staff with whom I worked during my Ph.D. study. Specifically, I would like to express appreciation to Arpamart Chanmeka, Deborah L. DeGezelle, Frances DeCoux, Hong Zhao, Hyeon Yong Park, Jiukun Dai, Sungmin Yun, Vivek Sharma, and Youngcheol Kang who gave me a lot of encouragement as friends and coworkers at the CII Benchmarking & Metrics program. My sincere appreciation is also extended to all the students in the CEPM program with whom I enjoyed taking classes and working on research projects together.

Last but most importantly, I would like to express my sincere gratitude to my family. Words can never express my deepest appreciation to my wife Youngyi, daughter Joowon, parents and parents-in-law for their constant love, encouragement, and support. Without their help, this dissertation would not have been possible.

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Austin, Texas
May, 2012

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The primary goal of this research is to provide quantitative information used for the implementation of project management attributes. Nineteen project management attributes and five project performance outcomes were investigated to examine their relationships. A series of statistical analyses were conducted to quantify the relationships between the implementation levels of the attributes and the probabilities for better project performance. The analyses utilized data from 212 projects collected by the Construction Industry Institute (CII) Benchmarking and Metric database from 2007 through 2010. The results showed that the beneficial effects of project management attributes varied depending on the implementation levels of project management attributes, the performance outcome type, and whether the project was conducted by the owner or contractor organization. Quantified analysis results were provided by this research. Project management attributes were identified as critical if they were found to be significantly related to a particular performance outcome. Minimum implementation levels were provided for these critical attributes, as were results covering the combined effects of the critical attributes on performance outcomes. Based on the analysis results, the research generated specific and quantitative information used in implementing project management attributes for better performance. This information will help practitioners achieve improved project performance in the most effective and efficient way, and thus it is the practical contribution of this research. From an academic point of view, this study designed a data analysis process by a series of statistical analysis methods which makes it possible to examine the relationships between project management attributes and various project performance outcomes in a quantitative manner.

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CHAPTER 1: INTRODUCTION

1.1 Problem Statement

The construction industry business environment is more competitive than ever. Challenges from skilled labor shortages, rapidly changing technology, fluctuating financial markets, tight budgets and globalization of construction markets are hallmarks of the twenty first century. Furthermore, due to the complex nature of the construction process and its multi-disciplinary nature, delivering capital facility projects is demanding. Industry and academia have endeavored to improve project performance by identifying key performance indicators (KPIs), critical success factors (CSFs), and project management knowledge. Nonetheless, many projects still fail to achieve expected performance outcomes because they lack clear guidance on selecting and implementing the most effective project management attributes (Ivory and Alderman 2005; Kanter and Walsh 2004; Matta and Ashkenas 2003). Project management attributes can be defined as methods, tools, characteristics, and factors that can lead to better project performance when they are appropriately implemented or executed.

The construction industry recognizes that project management attributes are essential to completing capital facility projects successfully (Ling et al. 2009; Ramirez et al. 2004). Recognizing their potential value, a number of project management attributes have been developed and introduced to the construction industry. Many studies have been conducted to assess their relationship with project performance (CII 1997). It has been reported that the implementation of project management attributes has a positive relationship with a successful project performance (Besner and Hobbs 2006; CII 2010; Ibbs and Kwak 2000; Lee et al. 2005a; Yasin et al. 2002).

Despite many studies to identify and assess project management attributes, there is a deficiency in published research dedicated to the analysis of how much effort was put into the implementation of project management attributes in successful projects; on which project management attributes were more critically related to specific project performance outcomes such as cost performance, schedule performance, safety performance, quality performance, and business performance; and on what was the combined effect of project management attributes on specific project performance outcomes. A few of studies led by the Construction Industry Institute (CII) and its researchers (CII 2003; Lee 2001) examined the effects of project management attributes on project performance. However, the studies introduced a simple classification model or reported descriptive statistics with a limited number of project management practices, which was not a comprehensive analysis. Furthermore, project management attributes have been revised and reestablished in 2007. Therefore, it is timely and important to investigate the project management attributes comprehensively in order to support the development of strategies and plans for their most efficient and productive implementation.

1.2 RESEARCH GOAL AND QUESTIONS

The primary goal of the present study is to guide an effective implementation of project management attributes by analyzing the relationships between project management attributes and project performance outcomes from various perspectives. The results of the analysis will assist to establish the most effective and efficient project management implementation plan. The specific research questions examined are as follows:

1st Research Question: What is the level of effort required for the implementation of a given project management attribute for better performance?

The first research question identifies the minimum effectual implementation level for a project management attribute, where projects implemented at the identified level or above showed better performance than projects implemented below the identified level. There are many different combinations of project management attributes and project performance outcomes; this research question will test hypotheses for every possible combination.

2nd Research Question: Which project management attributes are significantly related to better project performance?

The second research question identifies project management attributes that are significantly related to improved project performance outcome. A project management attribute is considered a "critical" project management attribute when its high-level implementation was significantly related to better performance. This research question also involves testing hypotheses for every possible combination of project management attributes and project performance outcomes.

3rd Research Question: Which project management attributes are more influential on improved project performance?

The third research question determines the relative importance of the critical project management attributes identified by the analyses in Research Question 2. Although the critical project management attributes have been demonstrated to have a significant relationship with a project performance outcome, their relative impact of each one is likely to be different.

4th Research Question: What are the combined effects of critical project management attributes on project performance outcomes?

The last research question examines the effects of combined critical project management attributes on project performance outcomes by quantifying their relationship. The hypothesis is tested by demonstrating that a better project performance outcome was achieved as more effort was put into the implementation of critical project management attributes.

1.3 RESEARCH SCOPE AND DELIMITATIONS

The scope of this research is defined below:

The research is focused on the performance assessment of capital facility delivery as opposed to operations and also excludes the influence of economic and financial situations, social, political, or regulatory climates.

The data set is comprised of projects with a total project cost greater than $5M USD submitted to the CII Benchmarking & Metrics (BM&M) database from 2007 through 2010.

The key project performance outcome metrics used for assessing the performance of capital facility delivery include: Cost Growth; Schedule Growth; Budget Factor; Schedule Factor, Safety Achievement, Quality Achievement, and Business Object Achievement. The definitions of these metrics are described in detail in Chapter 3.

Nineteen project management attributes are included: accurate engineering deliverables; alignment; alliance; budget accuracy; change management; constructability; fast track; front end planning; partnering; percent design completion at authorization for expenditure; percent design completion prior to construction; percent modularization; planning for startup; project definition rating index; project delivery and contract strategy; project risk assessment; team building; zero accident technique; and timely engineering deliverable. Considered significantly important for achieving improved project performance, these attributes were developed and validated by construction industry experts who have participated with the CII. Additional studies sponsored by CII have reported that the implementation of each project management attribute included in this study positively impacts on project performance. Therefore, it is reasonable to conclude that this research analyzes the performance of capital facility delivery using data from the essential project management attributes collected by the CII questionnaire.

1.4 ORGANIZATION OF DISSERTATION

This dissertation is composed of five chapters. Chapter 1 formulates the problem statement, the research goal and questions, and the hypotheses, and the research scope. Chapter 2 presents a literature review, identifying gaps in the literature and summarizing the needs for this research. Chapter 3 presents the research methodology which includes a review of statistical analysis methods employed by the study. This chapter describes how each research question is quantitatively investigated. Chapter 4 presents data analysis results, divided into two sub-chapters: owner projects and contractor projects. Each sub-chapter summarizes five different project performance outcomes respectively and includes a discussion section. Finally, Chapter 5 covers the overall conclusions from the study and provides recommendations.

CHAPTER 2: LITERATURE REVIEW

This chapter presents findings from the body of literature focused on project performance improvement; the chapter is organized into three sections. The first section reviews the studies related to project performance measurement methods and critical success factors (CSFs). The second section presents project management attributes. Lastly, the third section documents gaps in the existing body of knowledge.

2.1 EFFORTS FOR IMPROVING PROJECT PERFORMANCE

Many studies have been conducted with the intention of providing the construction industry with proven methods that improve project performance. The studies range from attempts at developing project performance measurement methods to identification of critical success factors and project management attributes.

2.1.1 PERFORMANCE MEASUREMENT METHODS

Performance measurement is "the process of quantifying the efficiency and effectiveness of action (Neely et al. 2005)." The purpose of performance measurement in this context is to reasonably evaluate a project or company. The main topics addressed by studies on project performance measurement methods focus on what should be measured and how it should be evaluated and compared.

2.1.1.1 PERFORMANCE INDICATORS

Traditionally, the performance of construction projects has been measured using metrics that can be classified into three performance areas: cost, time, and quality (Ward et al. 1991). Recent studies have employed additional performance areas such as safety and business to evaluate construction project execution from a more balanced perspective. Table 2.1 shows the performance areas used by several previous studies. These five performance areas were utilized by most of the studies on which this research focuses. A survey by Cox et al. (2003) on construction executives and project managers in the construction industry also supports the importance of the performance areas with the exception of business. The consequence of business performance was reported as an important criterion by White and Fortune (2002), however. In addition to the five performance areas, environmental friendliness, project-team satisfaction, and communication effectiveness were also frequently included in the research. Some other areas found in the literature include technology transfer, change orders, productivity, building functionality, strategic performance, risk improvements, minimized conflicts, innovation, and improvement.

In order to utilize a simple and understandable measure, performance indicators, often called performance metrics have been developed. They are defined by either quantitative measures such as cost growth, schedule growth, budget factor, and schedule factor, or by qualitative measures using a Likert scale. Some of the performance indicators are often identified as key performance indicators (KPIs) due to their significant influence on project performance.

Table 2.1: Project Performance Areas

	Performance Areas								
	Cost	Time	Quality	Safety	Business	Environ-ment	Project-team Satisfaction	Communi-cation	Others
Kaplan and Norton (1992)	O	O	O	O	O				Innovation & Learning
Kumarasway et al. (1996)	O	O	O	O		O	O		Technology transfer
The Audit Office of New South Wales (1999)	O	O	O	O		O		O	
The KPI Working Group (2000)	O	O	O	O	O				Change orders
White and Fortune (2002)	O	O	O	O	O				
Cox et al. (2003)	O	O	O	O					Productivity
Chan and Chan (2004)	O	O	O	O	O	O	O		Functionality of building
Nitithamyong and Skibniewski (2006)	O	O	O					O	Strategic performance Risk improvement
Toor and Ogunlana (2010)	O	O	O	O			O		Minimized conflicts
Yeung et al. (2010)	O	O	O	O				O	Innovation and improvement

2.1.1.2 Performance Measurement Frameworks

An important role of performance measurement methods is to provide a reasonable evaluation framework to assess and compare performance outcomes. Many performance measurement frameworks have been developed for the construction industry. They measured different aspects of performance such as at the project level (Lee et al. 2005b), the company level (Yu et al. 2007), in terms of value management performance (Lin and Shen 2007), information communication technology adoption (Ahuja et al. 2010), and job performance (Hanna and Brusoe 1997). Despite their differences, the common objective was to develop a framework that evaluates performance in a reasonable fashion. The following paragraphs review the studies related to the Balanced Scorecard and benchmarking which are two of the most widely recognized performance measurement frameworks.

The Balanced Scorecard has been widely used and accepted since Kaplan and Norton (1992) introduced the concept. The main objective of the Balanced Scorecard is to obtain a balanced evaluation of performance from four perspectives: the customer; internal business; innovation and learning; and financial. Many studies have adopted and modified the Balanced Scorecard into their own advanced performance measurement framework. Kagioglou et al. (2001) presented a conceptual framework that integrated the perspectives of the project and the supplier with the Balanced Scorecard. Bassioni et al. (2005) established a conceptual framework to measure the business performance of construction companies by using the Balanced Scorecard, business excellence models, and empirical feedback from expert interviews. Yu et al. (2007) developed a framework to calculate performance scores by combining weighted metrics, which were categorized by the four Balanced Scorecard perspectives. The weights for the metrics were obtained by developing a model from data collected by a survey of construction companies. Luu et al. (2008) incorporated a strengths-weaknesses-opportunities-threats (SWOT) matrix into the Balanced Scorecard so that a typical construction company can devise their short- and long-term strategies.

An effective performance measurement method needs not only to select the right and balanced indicators, however, but also should provide performance targets and promote process changes for organizations to achieve improved performance. In this context, benchmarking may be the most advanced and comprehensive performance measurement method for improving project performance. CII (2011) defines benchmarking as "the systematic process of measuring an organization's performance against recognized leaders for the purpose of determining best attributes that lead to superior performance when adapted and utilized." Many researchers recognized benchmarking as an important tool to enhance the performance of projects and companies by identifying best project management attributes (El-Mashaleh et al. 2007; Ramirez et al. 2004). Furthermore, benchmarking is an important evaluation component of the Malcolm Baldrige National Quality Award criteria. Meybodi (2008) also reported that benchmarking is widely used by organizations that obtain ISO 9000 certification.

The heightened awareness over the past 15 years of the importance of benchmarking has prompted the initiation of benchmarking programs in several countries including Australia, Brazil, Chile, Denmark, the United Kingdom, the United States, Singapore, and the Netherlands. Costa et al. (2006) investigated these benchmarking initiatives and summarized their common objectives as follows:

- To offer guidance for performance measurement
- To provide benchmarks that can be used by individual companies to establish business goals and objectives
- To identify and disseminate best attributes in the industry through reports and benchmarking club networks

It was noted that most organizations who participated in benchmarking initiatives focused most on the first two objectives, however (Anderson and McAdam 2004; Costa et al. 2006; Hinton et al. 2000; Welch and Mann 2001). Without accomplishing the third objective, it is difficult for an organization to learn the best project management attributes and to change their processes.

2.1.2 CRITICAL SUCCESS FACTORS

There have been numerous research efforts that examined why there is difference in the scores of performance indicators. This knowledge is necessary to identify factors that have a causal relationship with performance indicators. These critical success factors (CSFs) are then given management focus in future projects. A number of studies have been done to identify CSFs affecting the success of construction projects. While Chan et al. (2004); Iyer and Jha (2006); and Sanvido et al. (1992) identified CSFs that are generally applicable to construction projects, Aksorn and Hadikusumo (2008); Chan et al. (2010); Chua et al. (1999); Dvir et al. (2006); and Li et al. (2005) focused on more specific CSFs that are tailored to particular objectives or project types.

Chan et al. (2004) reviewed major management journals and grouped influential factors under five categories: project-related factors, procurement-related factors, project management factors, project participants-related factors, and external factors. Although different categorization and numbers of attributes were found in previous studies, the CSFs organized by Chan et al. (2004) could be considered to be generally applicable to construction projects. Details for each category are summarized in Table 2.2.

Table 2.2: Factors Affecting Project Success

Category	Attribute
Project-related Factors	Project type, Project nature, Number of floors, Complexity
Procurement-related Factors	Procurement method, Tendering method
Project Management Factors	Communication system, Control mechanism, Feedback capabilities, Planning effort, Organization structure, Safety program, Quality program, Subcontractor control, Overall managerial actions
Project Participant-related Factors	Client's experience and ability, Client's nature, Client's organization size, Client's focus, Client's commitment, Team leaders' experience and skills, Team leaders' commitment, Team leaders' involvement, Team leaders' adaptability, Team leaders companies' support
External Factors	Economic environment, Social environment, Political environment, Physical environment, Industrial relation environment, Level of technology advanced

Owing to many CSF-related studies, factors affecting project success have been extensively identified for the construction industry. Nonetheless, most of these studies did not investigate how to manage or control the CSFs. As a result, the construction industry began to pay more attention to project management attributes involved in delivering capital projects (Ramirez et al. 2004). To increase the chances of achieving better project performance, it is necessary to identify and implement the best project management attributes. The next section reviews research efforts on project management attributes.

2.1.3 PROJECT MANAGEMENT ATTRIBUTES

Project management has obtained a reputation from industry and academia as a discipline that helps a project and organization achieve improved performance. Many efforts have been made to advance the knowledge of project management. The Project Management Institution (PMI) has taken a leading role in standardizing project management processes and knowledge areas, and published their fourth edition of "A Guide to the Project Management Body of Knowledge (PMBOK Guide)" in 2008, which is comprised of five project management processes and nine knowledge areas.

Since the first edition of the PMBOK was published in 1994, there has been considerable research on project management attributes to effectively manage a specific management process or knowledge area. Some researchers view project management attributes as just software, while others regard them as systematic procedures (Patanakul et al. 2010). This research applies the latter concept and follows CII's definition, "a project management attribute is a process or method that, when executed effectively, leads to enhanced project performance (CII 2011)."

Various project management attributes for project managers have been introduced (Kerzner 1999; Milosevic 2003). CII has formalized the elements for project management attributes to manage a capital facility project effectively. These elements are directly related to the activities that practitioners must do for a specific project management attribute. Besner and Hobbs (2004); CII (2010); Patanakul et al. (2010); Thamhain (1999); White and Fortune (2002) explored the usage levels of project management attributes by conducting a large-scale survey on industry practitioners. They calculated the levels of project managers' familiarity with project management attributes and the levels of usage for various project sizes and durations. Besner and Hobbs (2004) identified patterns of project management attributes use by employing principal component analysis and demonstrated that practitioners have a tendency to use project management tools and techniques in groups or toolsets. In addition, Ibbs and Kwak (2000) developed a project management maturity model to reasonably assess the maturity of project management attributes.

Meanwhile, there has significant research effort focused on the effects of project management attributes on project performance. Most of these efforts explored the impact of one selected project management process or knowledge area (Yang et al. 2006; Raz and Michael 2001). One the other hand, some researchers have investigated project management attributes from a multivariate perspective. Zwikael (2009) presented the relative importance of the PMBOK Guide's nine knowledge areas as applied during project planning phase in order to identify those areas that are more likely to result in successful project outcomes. Besner and Hobbs (2006) and Yasin et al. (2002) prioritized project management attributes by surveying industry practitioners' perceptions. CII reported the value of project management attributes several times (CII 1999; CII 2003; CII 2010; Lee et al. 2005a) with descriptive statistics.

None of the previous research efforts provided an in-depth analysis between the level of project management attributes implemented and project performance. Therefore, it is necessary to identify which project management attributes are related to better project performance for a specific project performance outcome. Furthermore, the appropriate implementation levels for better project performance and their combined effect on project performance remains to be ascertained.

As described in Section 1.3 Research Scope and Delimitations, this research examines 19 project management attributes captured by the CII questionnaire as established by the CII BM&M program in 2006 after several years of survey refinement. These attributes were incorporated into the CII questionnaire based on the decisions of the CII BM&M committee that consists of approximately 20 experts from industry and academia. The following sections briefly describe the 19 attributes, by grouping them into two sub-sections: best attributes and other common project management attributes. The first sub-section covers best attributes that were established by CII research activities. The second subsection covers other common project management attributes that are generally considered to be an important to project performance. The measurement approach for each group is different. Best attributes are measured by multiple elements, while other common attributes are measured by a single element. Section 3.5.2 describes measurement methods in detail. The project management attributes reviewed in the following sections are used for explanatory variables in this research to investigate their possible effect on project performance.

2.2 Project Management Attributes in This Study

2.2.1 CII Project Management Attributes

This research covers 11 CII project management attributes, including alignment; change management; constructability; front end planning; partnering; planning for startup; project definition rating index; project delivery and contract strategy; project risk assessment; team building; and zero accident technique. Formed by the collaboration between the construction industry and academia, CII research teams developed and validated these best attributes. The following sections review previous research and provide a foundation for understanding each of the best attributes. The data collection instrument for each best attribute is provided in Appendix A.

2.2.1.1 Alignment

Alignment is defined as "the condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives (CII 2011)." In general, project team members come from different organizations or functional groups, and their values and goals can conflict during a project. In such an environment, the project objectives must be aligned across project participants. CII research report (Rowings 2003) has shown that properly aligned objectives positively affect the project team and help resolve conflicts and overcome barriers to the benefit of all project participants. There are three dimensions to accomplish alignment: top-to-bottom alignment within an organization, cross-organizational alignment between functional groups within an organization, and alignment of objectives throughout the project life cycle (Gibson et al. 2009). The process of gaining proper alignment requires team leadership, definition of project goals and priority, a trust culture, timely and productive team meetings, two-way communication, a clear operation and maintenance philosophy, a reward system for alignment, evaluation of alignment, and use of the alignment tool.

2.2.1.2 CHANGE MANAGEMENT

CII (2011) defines change management as "the process of incorporating a balanced change culture of recognition, planning, and evaluation of project changes in an organization to effectively manage project changes." Changes can occur during the entire project life-cycle for various reasons. Handling changes is important to achieving the expected project performance outcomes, because the impacts from changes can be complex and significant regardless of their type and magnitude. Many researchers (Hanna 2001; Hester et al. 1991; Ibbs and Allen 1995) have reported the negative impact of changes on a project and argued that significant cost savings can be achieved by effective change management. Ibbs and Backes (1994) suggested that the principles of effective change management include promoting a balanced change culture, recognizing change, evaluating change, implementing change, and improving from lessons learned. Based on these principles, the level of effective change management is evaluated by the following elements: existence of a formal process, clear specification in the contract, key personnel's understanding, timely management, owner authorization, communication, evaluation of possible changes in the design phase, and timely authorization.

2.2.1.3 CONSTRUCTABILITY

O'Connor and Tatum (1986) defined constructability as "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives." In other words, incorporating the effective and timely integration of construction knowledge into a project helps complete it in the best possible time with accuracy at the most cost-effective levels (CII 2011). Maximum benefits can be realized when people who have construction knowledge and experience are involved in the early stages of a project (O'Connor and Tatum 1986; Russell et al. 1992). Implementation of project-level constructability includes four processes: 1) obtaining constructability capabilities, 2) planning for constructability implementation, 3) implementing constructability, and 4) updating corporate program (O'Connor 2006). Successful implementation of constructability requires the following elements: company's support for the constructability program, tracking of constructability lessons learned, coordinator commitment, effective communication between construction and design personnel, documentation, integration with the execution plan, identification of constructability barriers, incorporation of relevant information, and reflection of recommendations in engineering deliverables.

2.2.1.4 Front End Planning

CII (2011) defines Front-End Planning (FEP) as "the essential process of developing sufficient strategic information with which owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project." Gibson et al. (2006) emphasized that the importance of FEP in delivering capital facility projects has long been recognized by the construction industry, reviewing the FEP-related research efforts and summarizing lessons learned. They demonstrated the positive relationship between the level of FEP effort and project performance. Considered an important research and knowledge area, CII has funded many research teams to investigate FEP from various perspectives since the 1990s (Gibson and Tucker 1994). There are three main phases in FEP: feasibility study, concept development, and detailed scope development. The processes carried out during FEP includes organizing the project team, choosing technology, selecting the project site, developing project scope, and developing alternatives. The evaluation criteria for FEP include team skill, team representativeness, team commitment, definition of team roles, effective communication, completeness of documentation, clear owner's objective, analysis of technologies, assessment of alternative sites, risk analysis and strategies, regulatory permission, scope definition, and budget and schedule alignment.

2.2.1.5 Partnering

Partnering is "a commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant's resources (CII 2011)." The partnering relationship is based on trust, dedication to common goals, and a shared culture beyond organizational boundaries. Thomson et al. (1996) identified that successful partnering requires establishing solid trust, having top management's support, establishing win/win objectives, addressing internal barriers, leveraging the champions' role in the directing process, and developing measures keyed to objectives. They also reported that long-term partnering can provide a competitive advantage for the U.S construction industry. Sanders (1996) identified the five phases of the partnering process model: owner's internal alignment, partner selection, partnering relationship alignment, project alignment, and work process alignment. Measuring the implementation level of the partnering process includes the assessment of the following elements: companies' commitment to partnering, companies' experience with using partnering, the partnering agreement and relationship, the duration of partnering, and a partnering implementation plan.

2.2.1.6 Planning for Startup

CII (2011) defines startup as "the transitional phase between construction completion and commercial operations, that encompasses all activities that bridge these two phases, including systems turnover, check-out of systems, commissioning of systems, introduction of feedstocks, and performance testing." O'Connor et al. (1999) reported that planning for startup is essential to overall project success because many projects have significant startup costs, sometimes accompanied by expensive startup delays and a long-lasting negative impression. They identified management commitment, startup objectives, a startup execution plan and time-outs for analysis as the important keys to a success startup. The degree of implementation of planning for startup is evaluated by the following activities: clear definition of the startup objectives, effective communication of the objectives, appropriate resource allocation, clear team's roles, a formal startup execution plan, early identification of major startup systems, a startup schedule, incorporation of requirements submitted to procurement, the frequency of risk assessment, formal training, startup team involvement in the startup procedure, and a relevant system turnover plan.

2.2.1.7 PROJECT DEFINITION RATING INDEX

The Project Definition Rating Index (PDRI) is a tool used for measuring project scope definition for completeness at the time prior to project authorization (Gibson and Dumont 2009). The PDRI provides and describes elements for consideration in the form of a checklist to ensure the development of a good scope definition package. The degree of project scope definition for completeness can be represented by a PDRI score ranging from 70 to 1000. A PDRI score of 200 or less has been shown to correlate with successful projects (Gibson and Dumont 1995). The PDRI consists of three main sections: basis of project decision, basis of design, execution approach. The first section focuses on defining project objectives; the second section describes processes and technical information elements; and the last section deals with the requirements of the owner's execution strategy. Each of the sections is further divided into multiple categories and elements to ensure that the scope of a project is defined in detail.

2.2.1.8 PROJECT DELIVERY AND CONTRACT STRATEGIES

Project Delivery and Contract Strategies (PDCS) defines the roles and responsibilities of project participants and assists the owner in planning how to organize and pay project participants for their services to complete a project (Oyetunji and Anderson 2001). A structured process is necessary for establishing PDCS, including evaluating and prioritizing owner's objectives, reviewing and evaluating delivery methods and contract types, and determining what the appropriate delivery method and contract type for this project is (CII 2011). Ibbs and Oliver (1986) and Thomas et al. (2002) reported that there was difference in project performance outcomes between project delivery methods and contract types. In other words, an appropriate project delivery method and contract type might lead to better project performance. The evaluation of PDCS is done by the following criteria: considering alternative delivery methods and contract types, reviewing and prioritizing the business objectives, evaluating strengths and weaknesses of alternative project delivery methods and contract types, ranking project delivery methods and contract types in terms of suitability, and using an assistant tool for determining the project delivery method and contract type for the project.

2.2.1.9 PROJECT RISK ASSESSMENT

Project risk assessment is "the process to identify, assess, and manage risk (CII 2011)." Through the process, the project team evaluates risk factors and their potential impact on a project. Based on the evaluation, the team develops mitigation strategies for possible risk factors. Risk is usually considered uncertainty that leads to unfavorable project performance outcomes, although uncertainty may also result in favorable outcomes. Diekmann et al. (1988) and Neil and Diekmann (2010) stated that a total risk management approach needs risk identification, risk measurement, and risk control. When they are properly conducted, Walewski et al. (2003) reported that risk management provides: early identification of risks and opportunities, communication of risks among project participants, identification and management of uncertainty, acknowledgement of risk issues and mitigation actions, and enhanced risk-based decision-making. The evaluation of the level of risk management committed to a project includes the following elements: level of risk assessment, starting point of risk assessment, risk assessment update, the use of an outside facilitator, relevant team members' involvement, documentation of the risk assessment process, and the development and management of a mitigation plan.

2.2.1.10 TEAM BUILDING

Team building is "a project-focused process that builds and develops shared goals, interdependence, trust and commitment, and accountability among team members and that seeks to improve team members' problem-solving skills (CII 2011)." In the form of collaboration, Albanese (1993) reported that team building can facilitate development of an effective project management team and minimize adversarial relationships among owners, designers, and contractors due to mistrust, conflict and disputes. He also reported that good team building enables team members to complete projects ahead of time and under budget. Successful team building demands a formal team building process, the early start of the implementation of team building, one or more "retreat" type team building workshops, the use of an outside facilitator, relevant stakeholders' participation in the team building workshops, and a sufficient number of follow-up team building meetings.

2.2.1.11 ZERO ACCIDENT TECHNIQUES

CII (2011) documents "zero accident techniques include the site-specific safety programs and implementation, auditing, and incentive efforts to create a project environment and a level of training that embraces the mindset that all accidents are preventable and that zero accidents is an obtainable goal." In terms of the sanctity of human life, safety must be the first priority in carrying out a project. In addition, costs caused by accidents were not negligible. According to their estimation, Waehrer et al.

(2007) claimed that the total costs related to fatal and nonfatal injuries in the construction industry in 2002 were $11.5 billion and the average cost per case was $27,000. Many researchers have conducted research projects to develop safety programs and reported that effective safety programs reduced accidents (Hinze and Huang 2003; Hinze et al. 2006; Liska et al. 1993). The degree of implementation of zero accident techniques is evaluated by the following activities: a written site-specific safety plan, the safety supervisor's commitment, safety orientation, formal safety training, safety meetings, safety audits, alcohol and drug testing, near-miss investigation, rewards and the use of safety performance as a criterion for contractor selection, and safety risk evaluation in the design phase.

2.2.2 OTHER COMMON PROJECT MANAGEMENT ATTRIBUTES

In addition to the best attributes, this research includes the following 8 common project management attributes: fast-track, use of modularization, managing timely and accurate engineering deliverables, alliances, budget accuracy, percent design completion at authorization for expenditure, and percent design completion prior to construction. These attributes have been identified as significant and are included in the CII BM&M questionnaire. The data collection instruments for each attribute are provided in Appendix A.

2.3 SUMMARY OF LITERATURE REVIEW

Many research efforts have been devoted to performance improvement in the construction industry. Performance measurement methods have been developed to reasonably measure the performance of projects and companies. CSFs have been investigated to identify important factors that have a significant impact on project or company performance. Project management attributes have been established to effectively manage and advance project management processes. These cited studies have contributed to answering what to measure, how to measure, and what to do to improve project performance.

Nonetheless, little research has been found to answer the question "what are the appropriate project management attributes to use that could lead to better project performance?" Even though the reviewed project management attributes have been widely implemented, research has not adequately investigated as to how their use contributes to the success of a project. Furthermore, the contribution of project management attributes to project performance can be conditional. In other words, contribution can be determined based on the implementation level of project management attributes. The specific contribution of each project management attribute is likely to be different. To provide more helpful and practical information on the implementation of project management attributes, it is necessary to analyze and quantify the effects of project management attributes on project performance in detail.

Chapter 2 provided the background for this research and helped the reader to understand the context of project performance improvement. Previous studies related to project performance were reviewed and specific project management attributes used for this research were explained. Research gaps in previous studies were also discussed.

CHAPTER 3: RESEARCH METHODOLOGY

This chapter presents the research methodology used for this research. To begin, a discussion of the research design, research population, instrumentation, and data collection and validation process is presented. Next, the data analysis procedures and methods applied for data analysis in this research are specified in detail. The section describes step-by-step procedures in accordance with the research questions:

- 1st research question: What is the level of effort required for the implementation of a given project management attribute for better performance?
- 2nd research question: Which project management attributes are significantly related to better project performance?
- 3rd research question: Which project management attributes are more influential on improved project performance?
- 4th research question: What are the combined effects of critical project management attributes on project performance outcomes?

3.1 RESEARCH DESIGN

This research can be classified as a correlational and ex post facto research because its main purpose is to investigate possible cause-and-effect relationships between variables over which the researcher has no control. It is accomplished by observing the existing state of affairs and often by measuring frequency of the variables (Cohen et al. 2007; Kothari 2009). Since this research did not control the implementation level of project management attributes or project performance outcomes used for variables in this research, a correlational and ex post factor research method was selected to identify and investigate the relationships between project management attributes and project performance outcomes.

3.2 POPULATION AND SAMPLE

The population of this research is capital facility projects conducted by Construction Industry Institute (CII) member companies. Two hundred twenty eight projects were selected as a sample for this research. All of the projects were submitted by CII member companies to the CII Benchmarking & Metrics (BM&M) program during the period of 2007 to 2010. The rationale for their selection was that these projects involved data for the latest project management attributes. The data consisted of 146 projects from 32 owner companies and 66 projects from 20 contractor companies. Figure 3.1 shows some features of the 212 projects, including distributions by project nature, industry group, project location and project delivery system. Overall, the projects were evenly distributed in terms of project nature, industry group, and project delivery system. However, the majority of the projects were executed in the United States.

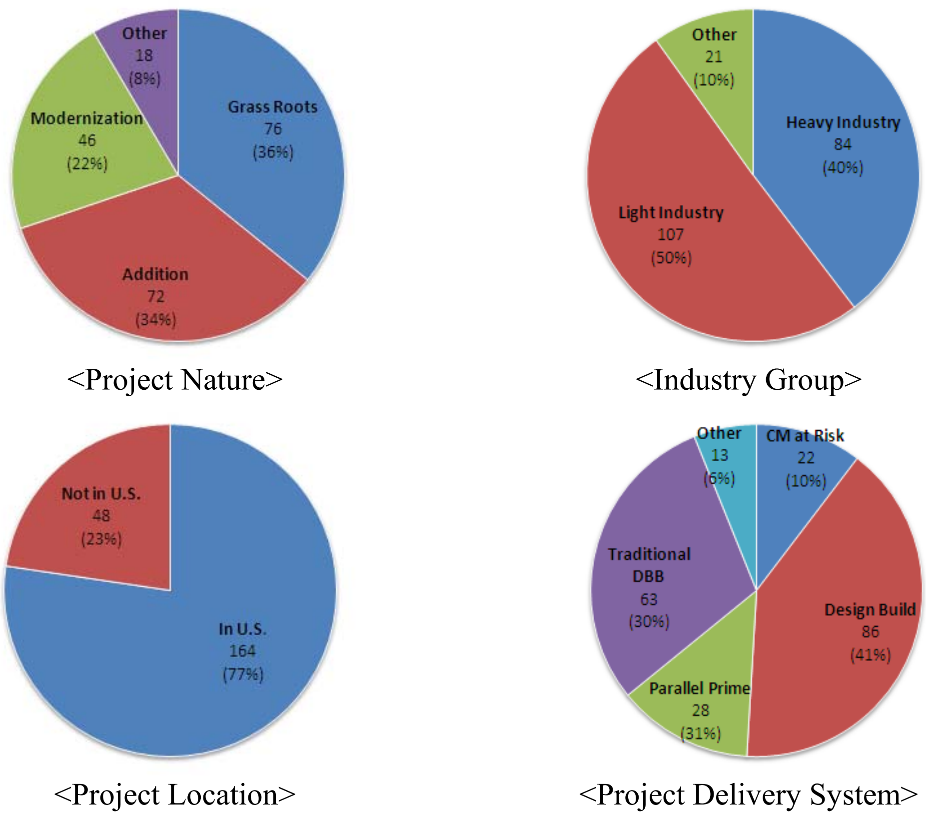


Figure 3.1: Research Population by Project Characteristics

Table 3.1 shows the characteristics of the 212 projects as grouped by the questionnaire respondent: either owner or contractor. Both groups showed approximately similar proportions of the projects by project nature. Light industry projects (68%) were more dominant than heavy industry projects (22%) for the owner projects. On the contrary, heavy industry projects took the largest proportion (78%) of the contractor projects. The majority of the projects were U.S. based. In terms of project delivery system, traditional design-bid-build was used by a majority of the owner projects and design build was predominant amongst the contractor projects.

Table 3.1: Frequency of Data by Project Characteristics

Project Characteristics		Questionnaire Respondent				Total (N=212)	
		Owner (N=146)		Contractor (N=66)			
Project Nature	Addition	51	(35%)	25	(38%)	76	(36%)
	Grass Roots	53	(36%)	19	(29%)	72	(34%)
	Modernization	33	(23%)	13	(20%)	46	(22%)
	Other	9	(6%)	9	(13%)	18	(8%)
Industry Group	Heavy Industrial	32	(22%)	52	(78%)	84	(40%)
	Light Industrial	100	(68%)	7	(11%)	107	(50%)
	Other	14	(10%)	7	(11%)	21	(10%)
Project Location	In U.S.	108	(74%)	56	(85%)	164	(77%)
	Not in U.S.	38	(26%)	10	(15%)	48	(23%)
Project Delivery System	CM at Risk	21	(14%)	1	(1%)	22	(10%)
	Design Build	42	(29%)	44	(67%)	86	(41%)
	Parallel Primes	25	(17%)	3	(5%)	28	(13%)
	Traditional D-B-B	53	(36%)	10	(15%)	63	(30%)
	Other	5	(4%)	8	(12%)	13	(6%)

3.3 INSTRUMENTATION

The 212 projects were collected through the CII questionnaire (Version 10.3) that was a web-based questionnaire located within the CII Benchmarking Project Central. The questionnaire has been developed and revised to reliably measure the performance of capital facility projects by construction industry experts and researchers who have participated in CII. In addition to performance data, survey questions also examine project management attributes endorsed by the construction industry. The development of the early phase of this web-based data collection instrument can be found in previous studies (Hudson 1997; Lee et al. 2005b).

The portion of the questionnaire relevant to this research is provided in Appendix A. The questionnaire excerpted from the CII questionnaire (Version 10.3) consists of three sections: 1) general project information, 2) project performance outcomes and 3) project management attributes. The general project information section collects data about project characteristics: project nature, industry group, project location, and project delivery method. In the project performance outcomes section, data necessary to calculate metrics for cost, schedule, safety, quality, and business are obtained. The project management attributes section covers 19 project management attributes used for analysis in this research. Some of the attributes have only one question to measure the implementation level, including alliance; budget accuracy; fast track; percent design completion at authorization for expenditure (AFE); percent design completion prior to construction; percent modularization; timely engineering deliverables; and accurate engineering deliverables. Other attributes have multiple questions to assess the implementation level, including alignment; constructability; change management; FEP; partnering; PDRI; PDCS; planning for startup; project risk assessment; team building; and zero accident technique. The scoring algorithm of the attributes that have multiple questions is discussed in the section of data analysis.

3.4 Data Collection and Validation Process

Data collection began in January of 2007 and was completed by December of 2010. The collected data for the 212 projects have been validated for consistency by CII account managers who are graduate research assistants working for the CII BM&M program. To ensure the validity of the data of the projects, CII account managers have reviewed them with each project owner who submitted the project data. After confirmation of the data, the project information was saved in the validated CII database. Figure 3.2 shows this validation process in detail.

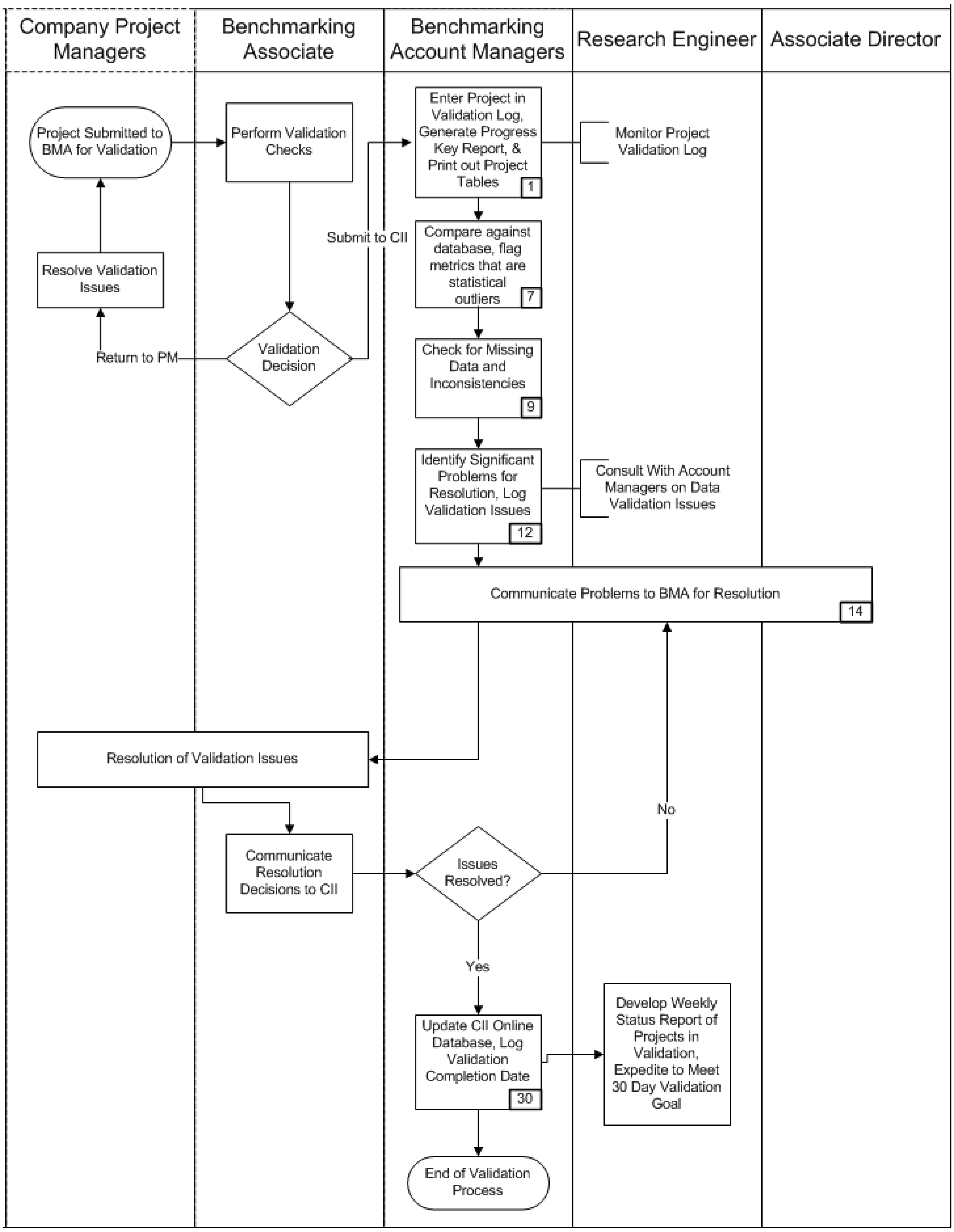


Figure 3.2: Data Collection and Validation Process

3.5 DATA ANALYSIS PROCEDURES & METHODS

3.5.1 INTRODUCTION

This research quantitatively examined the relationship between project management attributes and project performance outcomes. Since there is a difference in the use of project management attributes and the preferred performance metrics between owners and contractors, the research analyzed 146 owner projects and 66 contractor projects separately. Data analysis included 19 project management attributes for owner projects, but 16 project management attributes for contractor projects which did not have sufficient data for three project management attributes: project delivery and contract strategy, percent design completion at authorization for expenditure and percent design completion prior to construction.

Statistical analysis methods were used to identify possible patterns between project management attributes and project performance outcomes so that specific research questions could be answered. The contingency table analysis was applied to answer the first research question, "What is the level of effort required for the implementation of a given project management attribute for better project performance?" Linear, logistic, and probit regression analyses were used to answer the second research question, "Which project management attributes are significantly related to better project performance?" and third research question, "Which critical project management attributes are more influential on improved project performance?" Composite indexes that show a level of effort put into the implementation of critical project management attributes were used to answer the last research question, "What are the combined effects of critical project management attributes on project performance outcomes?" Figure 3.3 shows the overall flow of the data analysis procedures and methods.

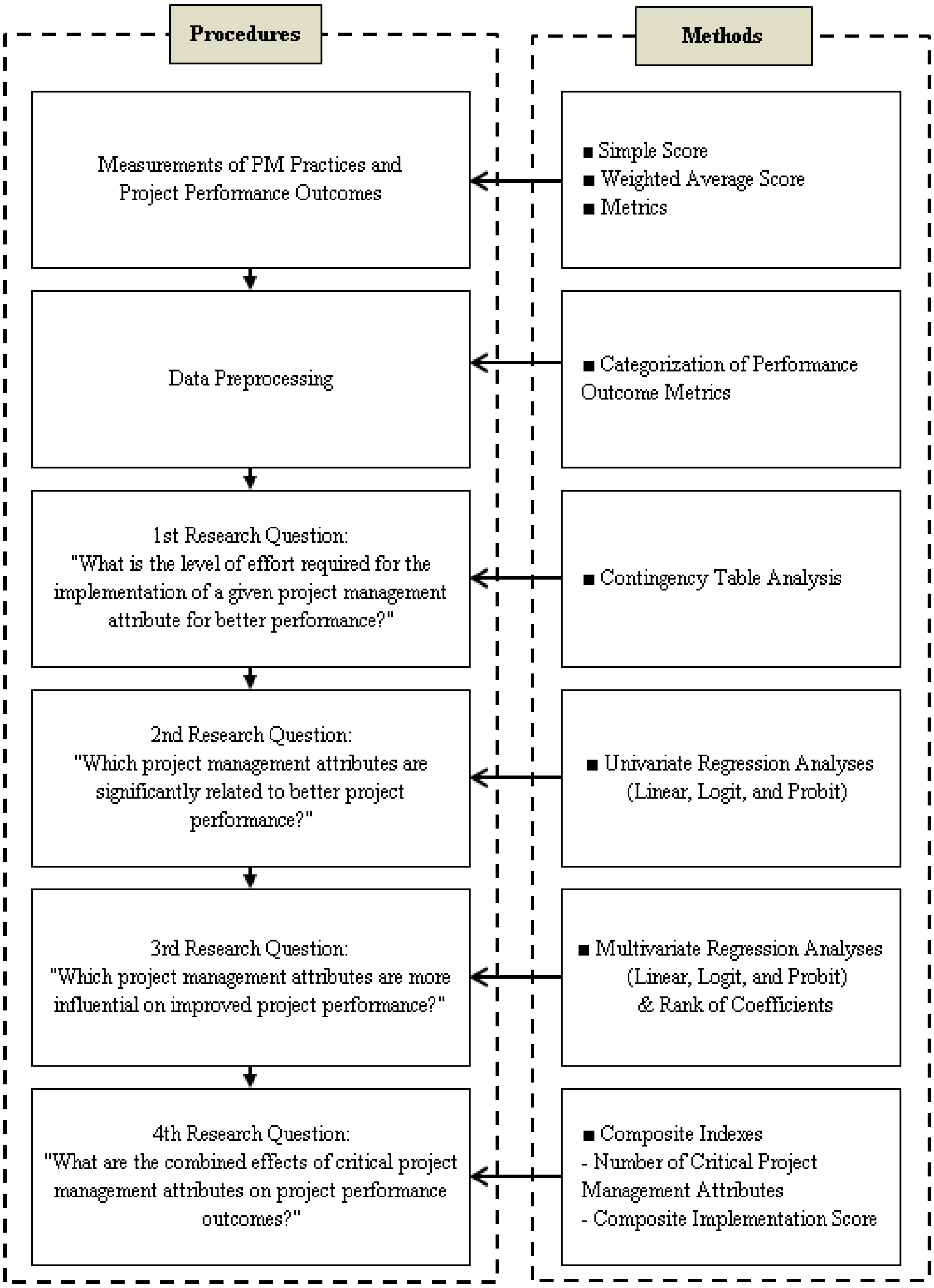


Figure 3.3: Overall Flow of the Data Analysis Procedures & Methods

3.5.2 MEASUREMENTS OF PROJECT MANAGEMENT ATTRIBUTES AND PROJECT PERFORMANCE OUTCOMES

The level of effort committed to implementing project management attributes was measured by scoring. There were two ways to score the implementation level of project management attributes. One was simply measured by a single question for alliance; budget accuracy; fast track; percent design completion at authorization for expenditure; percent design completion prior to construction; percent modularization; timely engineering deliverables; and accurate engineering deliverables. The other was scored by multiple questions for alignment; constructability; change management; FEP; partnering; PDRI; PDCS; planning for startup; project risk assessment; team building; and zero accident technique.

The scoring algorithm for the implementation level for each project management attribute with multiple questions was developed by the CII BM&M committee comprised of industry experts from owner and contractor companies and researchers from academia and CII (CII 2004). The score of each attribute was calculated as follows:

$$\text{Practice Score} = \frac{\sum_{i=1}^{n} S_i \times W_i}{\sum_{i=1}^{n} W_i}$$

where S_i - the score of question i; W_i - the weight of question i

Weights for each question used to calculate the attribute score were determined by the CII BM&M committee (Appendix B). Based on the weights and the respondents' answers, the implementation level for a project management attribute was scored. When the respondents did not answer a question, the weight for the question was not included in calculating the overall score of the implementation level. Consequently, without any impact from the not-answered questions, the scores of each attribute ranged in scale from 0 to 10 with zero indicating no use and ten indicating the most extensive use.

Project performance outcomes were quantified by metrics from different perspectives: cost, schedule, safety, quality, and business. Table 3.2 shows project performance outcome metrics and their definition. For safety performance, quality performance, and business performance, the level of meeting certain goals was measured by a Likert scale and used for both owner projects and contractor projects. However, for the cost performance metric, cost growth was used for owner projects, while budget factor was used for contractor projects. Similarly, for the schedule performance metric, schedule growth was used for owner projects and schedule factor was used for contractor projects. The rationale of the use of different cost and schedule metrics is that cost growth and schedule growth are preferred by owners and budget factor and schedule factor are preferred by contractors (Lee et al. 2005a). There are differences in handling of changes between growth metrics and factor metrics. Growth metrics measure actual cost or schedule versus initial planned cost or schedule without addressing changes. Factor metrics measure performance as a ratio of actual cost or schedule to initial planned cost or schedule with approved changes.

Table 3.2: Definition of Performance Outcome Metrics

Performance	Metric	Definition
Cost	Cost Growth	$\frac{\text{Actual Total Project Cost} - \text{Initial Planned Project Cost}}{\text{Initial Planned Project Cost}}$
	Budget Factor	$\frac{\text{Actual Total Project Cost}}{\text{Initial Planned Project Cost} + \text{Cost of Approved Changes}}$
Schedule	Schedule Growth	$\frac{\text{Actual Total Project Duration} - \text{Initial Planned Project Duration}}{\text{Initial Planned Project Duration}}$
	Schedule Factor	$\frac{\text{Actual Total Project Duration}}{\text{Initial Planned Project Duration} + \text{Duration of Approved Change}}$
Safety	Meeting Safety Goals	Not at All Successful (1) – 2 – 3 – Moderately (4) – 5 – 6 – Extremely Successful (7)
Quality	Meeting Quality Goals	Not at All Successful (1) – 2 – 3 – Moderately (4) – 5 – 6 – Extremely Successful (7)
Business	Meeting Business Goals	Not at All Successful (1) – 2 – 3 – Moderately (4) – 5 – 6 – Extremely Successful (7)

3.5.3 DATA PRE-PROCESSING

Those project performance outcome metrics that were response variables in this research were transformed into binary variables, as shown in Table 3.3. Originally, cost growth and schedule growth were continuous variables, and meeting safety goals, meeting quality goals, and meeting business goals were ordered categorical variables. However, analyses with them as they were did not produce meaningful results because of their large variation. Therefore, this research categorized the project performance outcome metrics into two groups for analysis. More importantly, since the objectives of this research involved finding the implementation levels for each project management attribute that correlated with better project performance and quantifying the impact of high-level implementation of project management attributes on project performance outcomes, it was necessary to categorically define response variables.

Table 3.3 specifies how the project performance outcome metrics were converted into binary variables. They were grouped into two categories: a better performance category and a worse performance category. Cost and schedule performance metrics were categorized by absolute criteria based on generally acceptable standards, while safety, quality, and business performance metrics were relatively categorized by the median because of their qualitative measurement. Approximately half of the projects answered "Extremely Successful" for safety, quality, and business and belong to the better performance category. The two-category division was chosen in order to assure that available sample sizes were sufficiently robust to produce significant results. Since this research divided 216 projects by owner or contractor for analysis, the numbers of data in each data set were not large enough to accommodate more categories. If more data were available, the research could have considered more categories.

Table 3.3: Categories for Project Performance Metrics

Performance	Metric	Better Performance Category	Worse Performance Category
		Criterion	Criterion
Cost	Cost Growth	< = 0	> 0
	Budget Factor	< = 1	> 1
Schedule	Schedule Growth	< = 0	> 0
	Schedule Factor	< = 1	> 1
Safety	Meeting Safety Goals	Above Median (Extremely Successful)	Below Median
Quality	Meeting Quality Goals	Above Median (Extremely Successful)	Below Median
Business	Meeting Business Goals	Above Median (Extremely Successful)	Below Median

3.5.4 IDENTIFICATION OF MINIMUM IMPLEMENTATION LEVELS FOR PROJECT MANAGEMENT ATTRIBUTES

This section describes the procedure used to answer the first research question, "What is the level of effort required for the implementation of a given project management attribute for better performance?" The basic idea is that if a certain project management attribute is implemented in only a limited fashion, the level of implementation may not be sufficient to produce better performance. For example, suppose that a project management attribute is implemented by a low level of effort and the probability of better performance is 20%. In this case, there is only a small probability that we can expect better performance. It is not a good strategy to exert effort in implementing a project management attribute to some extent but have a low expectation for better performance. In other words, it may be a better strategy to commit a sufficient level effort in implementing a project management attribute and in turn have a higher expectation for better performance.

To identify the minimum level of effort required implement a project management attribute with the expectation of better performance, this research applied the contingency table analysis (often called cross tabulation or frequency table analysis). The approach is generally used to analyze categorical variables. Table 3.4 shows an example of the structure of the contingency table analysis between two categorical variables: the M variable consists of the P or Q category and N variable consists of the R or S category. The contingency table analysis consists of two tables: observed frequencies and expected frequencies. The expected frequencies are calculated based on the observed frequencies ($E_{ij} = (O_{ij}+O_{i(j+1)}) \times (O_{ij}+O_{i(j+2)}) / (O_{ij}+O_{i(j+1)}+O_{i(j+2)}+O_{i(j+3)})$) that indicate the frequencies when M and N have no significant association.

Whether M and N have a statistically significant relationship can be tested by the chi-square statistic that measures the amount of disagreement between the observed frequencies and the expected frequencies. If a calculated chi-square statistic is more than a critical value used for the chi-square test, then the relation between M and N is statistically significant. It is noted that each of the expected frequencies need to be equal or more than 5 so that the chi-square test can be reliable. However, in such cases, the Fisher's exact test that most statistical packages provide for the contingency table analysis can be used as an alternative way for testing. The strength of the relationship between M and N can also be measured by the Phi (φ) coefficient that is equal to ($O_{11}O_{14}$ - $O_{12}O_{13}$) / square root of [(O_{11}+O_{12})(O_{13}+O_{14})(O_{11}+O_{13})(O_{12}+O_{14})]. More discussions about the contingency table analysis can be found in text books (Everitt 1992; Hill and Lewicki 2005; Rayner and Best 2000; Rudas 1997).

Table 3.4: Contingency Table (2 X 2)

Observed Frequencies		N		Total
		R	S	
M	P	O_{11}	O_{12}	$O_{11}+O_{12}$
	Q	O_{13}	O_{14}	$O_{13}+O_{14}$
Total		$O_{11}+O_{13}$	$O_{13}+O_{14}$	$O_{11}+O_{12}+ O_{13}+O_{14}$

Expected Frequencies		N		Total
		R	S	
M	P	E_{11}	E_{12}	$E_{11}+E_{12}$
	Q	E_{13}	E_{14}	$E_{13}+E_{14}$
Total		$E_{11}+E_{13}$	$E_{13}+E_{14}$	$E_{11}+E_{12}+ E_{13}+E_{14}$

Using the concept of the contingency table analysis, the implementation level of a project management attribute can be reasonably categorized into low-level implementation or high-level implementation. Table 3.5 shows the layout of the contingency table between a project performance outcome metric and the implementation level of a project management attribute. As described in Section 3.5.3 Data Pre-Processing, a project performance outcome metric is categorized into better performance or worse performance. Then, the implementation level can also be categorized based on a certain point, K, where a project performance outcome metric and the implementation level of a project management attribute have the largest strength relationship between them. Since the relationship can be quantified by the Phi (φ) coefficient {(ad-bc) / sqrt [(a+b)(c+d)(a+c)(b+d)]}, K can be identified by finding a point where the Phi (φ) coefficient is maximized. This research implemented a program in Excel to identify the point K.

Table 3.5: Contingency Table for Implementation Level of a Project Management Attribute and a Performance Outcome

		Implementation Level of a project management Attribute		Total
		Low-level Implementation	High-level Implementation	
		0 ~ K	K ~ 10	
Performance Outcome Metric	Better Performance	a	b	a+b
	Worse Performance	c	d	c+d
Total		a+c	b+d	a+b+c+d

The identified K optimally divided projects into two groups: 1) projects with better performance and high-level implementation or 2) projects with worse performance and low-level implementation. In other words, projects with better performance could be differentiated from projects with worse performance to the extent possible in terms of the implementation level of a project management attribute. Once the implementation level of a project management attribute was categorized based on the identified K, there was a maximized difference in the probability of performance between projects implemented at low-level implementation (0~K) and projects with high-level implementation (K~10). As a result, projects implemented at high-level showed the highest possible probability (b/b+d) for better performance and the lowest possible probability for worse performance (d/b+d). On the other hand, projects implemented at low-level showed the lowest probability (a/a+c) for better performance and the highest probability (c/a+c) for worse performance.

Whether there is a statistically significant difference in the two probabilities between (b/b+d) and (d/b+d) or (a/a+c) and (c/a+c) can be tested by the chi-square test, and the Fisher's exact test. The significant test result implies that projects implemented at high-level (>=K) showed much better performance than projects implemented at low-level (<K) for a project management attribute. Therefore, the identified point K can be considered as the minimum Minimum implementation level of a project management attribute. Based on the identified point K, this research divides the implementation level of each project management attribute into high-level or low-level. As a result, each project management attribute was used as a categorical variable with binary values which have either high-level or low-level in terms of the implementation. This was utilized for the next analysis procedures. After reviewing regression analysis methods, the following sections describe how this research analyzed the performance of projects with categorized implementation levels of project management attributes with regression methods.

3.5.5 REVIEW OF REGRESSION ANALYSIS METHODS

This research mainly used regression analysis methods to answer the second through the fourth research questions. The regression analysis methods included ordinary least squares (OLS), logit, and probit. The three regression methods were used to conduct univariate analyses for the second research question and multivariate analyses for the third research question. Based on the results of the second and the third research questions, the regression methods were also applied to answer the fourth research question. The following sections review the concepts and theories for the three regression analysis methods and discuss their pros and cons.

3.5.5.1 ORDINARY LEAST SQUARES REGRESSION

OLS regression is a method that represents a relationship between the response variable (y) and the explanatory variables ($x_{k,}$ k: number of explanatory variables) with an equation of a linear function ($y_i = \alpha + \beta_k x_k$). OLS is usually used when the response variable is continuous. The basic idea of OLS is to fit a unique straight line ($\hat{y}_i = \hat{\alpha} + \hat{\beta}_k x_k$) that minimizes the sum of the squared residuals (SSR). If y_i denotes the observed value and $\hat{y}_i$ denotes the expected value for the ith individual, then SSR equals to $\sum_{i=0}^{n}(y_i - \hat{y}_i)^2$. Residuals indicate vertical distances between the data points and a fitted line, as shown in Figure 3.4.

The regression coefficient ($\hat{\beta}$) in the equation for a fitted line indicates that for each unit increase in x, it is expected that there is an increase in y by $\hat{\beta}$. In addition,

$\hat{\beta}$ derived from a sample can represent the unknown parameter β for the population with a confidence interval. For example, a 95 percent confidence interval for β is $\hat{\beta}$ ± 1.96 standard error of $\hat{\beta}$. The standard error of $\hat{\beta}$ is equal to the square root of the square of the regression standard error ($\hat{\sigma}$) divided by the total variation of the explanatory variable (x_i) from its mean ($\bar{x}$), represented by the formula:

$$\text{Standard error of } \hat{\beta} = \sqrt{\frac{\hat{\sigma}^2}{\Sigma(x_i - \bar{x})^2}} \quad \text{where } \hat{\sigma} = \sqrt{\frac{\Sigma(y_i - \hat{y}_i)^2}{n-k-1}}$$

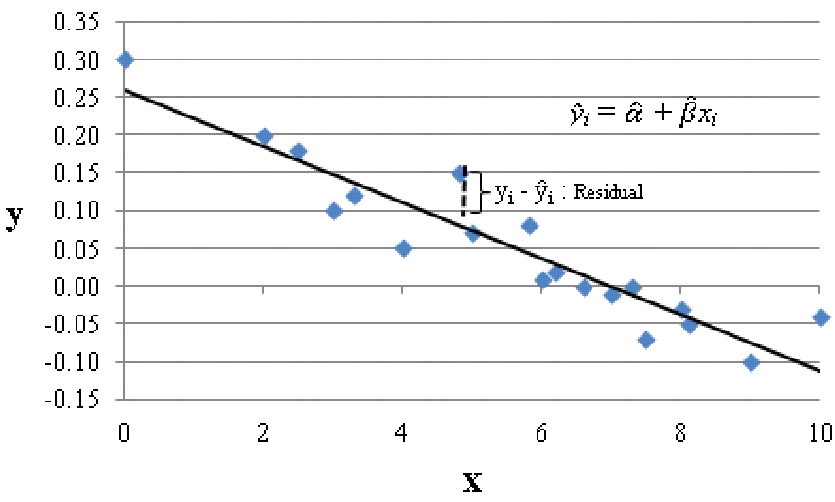


Figure 3.4: An OLS Regression Fitted Line

The goodness of fit of the fitted equation can be reviewed with standardized statistics: R^2 and F-statistic. R^2 indicates how much the total variation (total sum of squares (TSS)) in y is accounted for by the fitted equation and is defined by the formulae:

$$R^2 = \frac{\Sigma(\hat{y}_i - \bar{y})^2}{\Sigma(y_i - \bar{y})^2} = 1 - \frac{SSR}{TSS}$$

In other words, since SSR is unexplained variation for the response variable, R^2 (= 1 − SSR/TSS) shows the proportion of the variation in y that is explained by the fitted equation, ranging from 0 to 1. Another goodness-of-fit statistic is F-statistic that can be written as:

$$F(df_0 - df_1, df_1) = \frac{SSR_0 - SSR_1}{(df_0 - df_1)(\frac{SRR_1}{df_1})}$$

where 0 represents the null model, $y = \alpha$;

1 represent the full model, $y = \alpha + \beta x$.

It is basically to assess the effect of an explanatory variable in the equation by comparing before and after the variable has been added. With the information of the calculated F-statistic, the p-value that shows that the relationship happens just by chance can be computed. As a result, the significance of the variable can be evaluated.

There are assumptions that justify the use of OLS regression:

- Linearity: A linear relationship between response and composite of the explanatory variables
- Homoscedasticity: Residual has the mean of zero and a constant variance
- Normality of residuals: Residual is normally distributed
- Independent error terms: Residual is uncorrelated from one observation to another
- No influential outliers
- No Multicollinearity: Explanatory variables are not significantly correlated with each other
- No measurement error

If these assumptions are violated, a fitted regression model may be inefficient or biased for explaining the relationship between response and explanatory variables.

3.5.5.2 LOGIT/ PROBIT REGRESSION

Logit regression and probit regression are a type of generalized linear models used when the response variable is not continuous but categorical. Both of them model the relationship between the probabilities of an event occurring and the explanatory variables. The relationship is considered non-linear and follows an s-shaped curve, shown in Figure 5 because the probabilities of an event occurring range from 0 to 1. In order to interpret the relationship in a linear manner, a suitable link function is applied to transform the probabilities. Depending on the assumption of the underlying distribution of the probabilities, logit or probit is applied. Logit is used when the distribution is assumed to follow the logistic distribution, while probit regression is used when the distribution is assumed to follow the standard normal distribution. Logit uses the logit function (Logit (p) = ln $(\frac{\hat{p}}{1-\hat{p}}) = \hat{\alpha} + \hat{\beta}x$) and transforms the response variable into the logit variable. On the other hand, probit uses the inverse normal cumulative distribution function (Probit (p) = $\Phi^{-1}(p) = \hat{\alpha} + \hat{\beta}x$, here $\Phi(p) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{p} e^{-\frac{1}{2}t^2} dt$) that transforms the response variable into the probit variable.

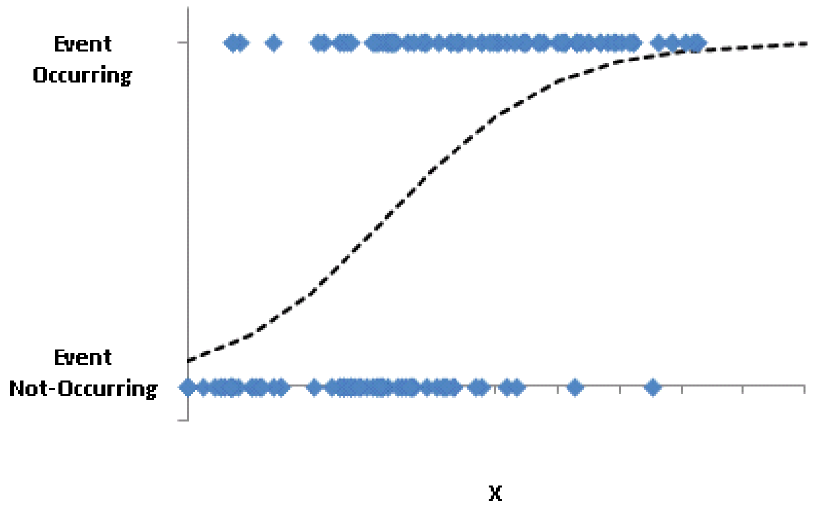


Figure 3.5: S shaped Fitted Curve

After the transformation based on the underlying distribution, the unknown parameters are estimated by the maximum likelihood approach in which the likelihood of obtaining a sample data is as high as possible. The maximum likelihood estimation is widely used for parameter estimation in non-linear statistical modeling techniques (Myung 2003). Suppose that the number of an event occurrence in a sample data is R out of N trials and thus produces a probability p of an event occurrence (= R/N). Then, for a particular choice of the unknown parameters α and β_k, the corresponding probability p for the explanatory variables can be calculated. Accordingly, the probability of an event occurring can be calculated, called the likelihood of the sample data. To find the best choice of α and β_k, an iterative process continues until the maximum likelihood is reached.

The coefficients (β_k) of logit indicate the change in the log odds of an event occurrence for a one unit increase in the *k*th explanatory variable. It is easier to interpret the coefficients with an odds ratio computed by raising the base of the natural log to the β^{th} power. When an odds ratio of an explanatory variable is equal to 1, greater than 1, or less than 1, it is implied that the explanatory variable has no effect, a positive effect, or a negative effect on the odds of an event occurring respectively. On the other hand, the coefficients (β_k) of probit show the change in the z-score for a one unit change in the *k*th explanatory variable. However, the interpretation of the coefficients of probit is not straightforward because the change in probability varies depending on the starting value of the explanatory variable. For example, there is a difference in the probability between the one unit increase from 0 to 1 and the one unit increase from 1 to 2 in an explanatory variable.

Goodness of fit for both the logit and the probit regression models can be evaluated by the Hosmer and Lemeshow test by which the null hypothesis of a good model fit is tested. Comparing observed and predicted classifications can also show a level of goodness of fit. In addition, the Cox & Snell R^2 and the Nagelkerke R^2 can be used as supplementary for goodness of fit. These are variations of the R^2 concept used for the OLS regression model and are used as supplementary statistics for goodness of fit (Peng et al. 2002).

There are assumptions that justify the use of logit and probit:

- Linearity

  ▪ Logit: A linear relationship exists between the log odds of the occurrence of an event related to the response variable and the composite of the explanatory variables

  ▪ Probit: A linear relationship exists between the inverse normal cumulative distribution probability of the occurrence of an event related to the response variable and the composite of the explanatory variables

- Independent error terms: Residual is uncorrelated from one observation to another
- No influential outliers
- No Multicollinearity: Explanatory variables are not significantly correlated with each other
- No measurement error:

If these assumptions are violated, a fitted regression model may be inefficient or biased for explaining the relationship between response and explanatory variables.

3.5.5.3 COMPARISON OF OLS/ LOGIT/ PROBIT REGRESSION METHODS

Table 3.6 describes the comparison of OLS, logit, and probit regression methods. When the response variable is continuous, OLS is more appropriate than logit or probit. However, when the response variable is categorical, logit and probit are more appropriate than OLS because the normal distribution assumption of the response variable is violated in OLS. With the explanatory variables, OLS fits the values of the response variable, while logit and probit fit the probabilities of an event occurrence of the response variable. Consequently, OLS has a linear relationship between the response and the explanatory variables as they are, but logit and probit need a link function that transforms the response variable so that a non-linear relationship between the probabilities of an event occurrence of the response variable and the explanatory variables can be transformed into a linear relationship. Applied link functions are $\ln\left(\frac{p}{1-p}\right)$ for logit and $\Phi^{-1}(p)$ for probit by which a linear relationship is established with the explanatory variables. Logit and probit are often called a linear probability regression, while OLS is called a linear regression.

For estimating unknown parameters that are the coefficients of a fitted equation, OLS uses the least squares estimation method, while logit and probit apply the maximum likelihood estimation method. Although the two estimation methods are different, they generate the same coefficients for the linear regression model when the response variable is normally distributed (Kleinbaum and Klein 2002). To test the significance of estimated coefficients, the three regression methods use different statistics: the t statistic for OLS, the Wald statistic for logit, and the z statistic for probit according to their underlying distribution.

However, the rationales behind the tests are the same, examining whether the coefficient of an explanatory variable is significantly large compared to its standard error. When a test for the coefficient of an explanatory variable is significant at α, it is implied that the explanatory variable has a significant effect on the response variable at the significance level α.

In regards to goodness-of-fit, OLS has a generally accepted statistic, R^2 that indicates the proportion of the variation in the response variable explained by explanatory variables in the model. In addition, the F-test can test the significance of goodness-of-fit. On the other hand, logit and probit use Cox & Snell R^2 and Nagelkerke R^2 that are similar to the concept of R^2 used for OLS. The significance of goodness-of-fit can be tested by the Hosmer and Lemeshow test.

There are pros and cons in using the three regression methods. Since OLS fits an equation without transformation, it is the easiest and most intuitive approach to interpret the coefficients of the explanatory variables in its equation. Logit is the next best approach because its coefficients are interpreted with the odds term. It is difficult to interpret the coefficients of probit in a simple, quantitative manner. Although the coefficients of logit are approximately (π/sqrt(3)) times larger than those of probit, they have almost the same standardized impacts of explanatory variables (Long 1997). In assessing goodness-of-fit, R^2 that is recognized as a standardized statistic is used for OLS. Although Cox & Snell R^2 and Nagelkerke R^2 are used for logit and probit, the use of these statistics has a limitation because the meaning of variance has not been clarified and their predictive efficiency has not been tested (Menard 2000). For assumptions necessary to be satisfied, logit and probit are more robust than OLS.

Table 3.6: Comparison of OLS, Logit, and Probit Regression Methods

	OLS	Logit	Probit
Best fit	Continuous response variable	Categorical response variable	
Linear relationship with explanatory variables	Response variable	Log of odds ratio of an event occurrence of response variable	Inverse normal cumulative distribution of an event occurrence of response variable
Estimation method	Least squares	Maximum likelihood	
Statistic used for testing the significance of coefficients	t	Wald	z
Goodness-of-fit	R^2; F-Test	Cox & Snell R^2 and Nagelkerke R^2; Hosmer and Lemeshow Test	
Pros and cons	Easiest to interpret	Easy to interpret	Difficult to interpret
	Standardized model fit statistic	No standardized model fit statistic	
	Stringent assumptions	Less stringent assumptions	

3.5.6 IDENTIFICATION OF CRITICAL PROJECT MANAGEMENT ATTRIBUTES

This research defines a "critical" project management attribute as a project attribute that had a significant relationship with a project performance outcome. Three regression analysis methods: OLS, logit and probit were used to answer the second research question, "Which project management attributes are significantly related to better project performance?" The three methods were conducted to examine whether the implementation level of a project management attribute was significantly related to a project performance outcome in a univariate manner. The level of a project management attribute was dealt with from two perspectives: one as a continuous variable and the other as a categorical variable. In other words, one analysis examines whether a project performance outcome was related to the continuous implementation level of a project management attribute that ranges from 0 to 10. The other analysis examines whether a project performance outcome was related to the categorical implementation level of a project management attribute that is either high-level implementation or low-level implementation as described in Section 3.5.4. This investigates whether there was a significant difference in project performance between projects implemented at high-level and projects implemented at low-level for a project management attribute. For each project management attribute, if its continuous implementation level was considered significant, its categorical implementation level was always considered significant, but the vice versa was not always true. Therefore, it is implied that a project management attribute implemented over a certain level can have a significant impact on a project performance outcome even though a continuous relationship is not identified between them.

When the three regression methods simultaneously showed a significant test result at the .10 level in either the categorical implementation level or the continuous implementation level, a project management attribute was regarded as a critical project management attribute. This demonstrates that high-level implementation of such a critical project management attribute was significantly related to better performance. Table 3.7 shows an example of critical project management attributes identified by the three regression methods. The example indicates that there are 12 critical project management attributes that are significantly related to cost growth among the 19 project management attributes.

Table 3.7: Example of the Identification of Critical Project Management Attributes

* Significance at α=0.10

	Project Management Attribute		OLS	Logit	Probit	Critical Project Management Attribute For Cost Growth Performance
1	PDRI	Categorical	*	*	*	*
		Continuous				
2	FEP	Categorical	*	*	*	*
		Continuous	*	*	*	*
3	Alignment	Categorical	*	*	*	*
		Continuous	*	*	*	*
4	Partnering	Categorical	*	*	*	*
		Continuous	*	*	*	*
5	Team Building	Categorical				
		Continuous				
6	Change Management	Categorical	*	*	*	*
		Continuous				
7	PDCS	Categorical	*	*	*	*
		Continuous				
8	Constructability	Categorical				
		Continuous				
9	Project Risk Assessment	Categorical				
		Continuous				
10	Planning for Startup	Categorical	*	*	*	*
		Continuous				
11	Zero Accident Technique	Categorical				
		Continuous				
12	Timely Engineering Deliverables	Categorical	*	*	*	*
		Continuous	*	*	*	*
13	Accurate Engineering Deliverables	Categorical	*	*	*	*
		Continuous	*	*	*	*
14	Percent Design Completion at AFE	Categorical	*	*	*	*
		Continuous	*	*	*	*
15	Percent Design Completion prior to Construction	Categorical	*	*	*	*
		Continuous	*	*	*	*
16	Alliance	Categorical	*	*	*	*
		Continuous	*	*	*	*
17	Budget Accuracy	Categorical				
		Continuous				
18	Fast-track	Categorical				
		-				
19	Modularization	Categorical				
		Continuous				

3.5.7 Relative Importance of Critical project management Attributes on Project Performance Outcomes

To answer the third research question, "Which project management attributes are more influential on improved project performance?" three multiple regressions analyses were also used. The results from the three regressions determined the relative importance of the critical project management attributes on a project performance outcome. When a multiple regression was conducted, a fitted regression equation ($y = \alpha + \beta_k x_k$) showed the coefficients ($\beta_1, \beta_2, \beta_3 \ldots \beta_k$) of each critical project management attribute. By comparing the size of the coefficients, the relative importance of the critical project management attributes for a project performance outcome could be evaluated and represented by their ranks. A critical project management attribute with a larger coefficient indicates that it is relatively more important than other critical project management attributes and thus higher ranked.

In this research, the average rank of the coefficients assessed from the three multiple regressions was used to determine the overall relative importance of the critical project management attributes for a project performance outcome. The use of the average rank from the three different regressions was intended to provide a more objective evaluation. Table 3.8 shows an example how the rank average determines the relative importance. According to the coefficient sizes, the ranks of the critical project management attributes are determined in each regression method. For example, among the 12 critical project management attributes, PDRI ranks second, third, and second in three regression results. The overall rank is determined by comparing the average of the ranks of the three regressions. The average is 2.333 for PDRI, making it rank second overall in relative importance.

Table 3.8: Example of the Overall Relative Importance

	Project Management Attribute (High or Low Implementation Group)	Linear		Logit		Probit		Overall	
		Coeff.	Rank	Coeff.	Rank	Coeff.	Rank	Rank Average	Rank
1	PDRI (High: >=8.7, Low: <8.7)	0.263	1	3.257	1	1.148	1	1.00	1
2	FEP (High: >=7.7, Low: <7.7)	0.186	4	1.427	3	0.684	2	3.00	3
3	Alignment (High: >=5.7, Low: <5.7)	0.150	5	0.910	5	0.393	5	5.00	5
4	Partnering (High: >=6.3, Low: <6.3)	0.208	3	1.339	4	0.618	3	3.00	4
5	Change Management (High: >=8.1, Low: <8.1)	0.120	6	0.903	6	0.361	6	6.00	6
6	Project Delivery Contract Strategy (High: >=8.3, Low: <8.3)	-0.004	12	-0.011	12	-0.067	12	12.00	12
7	Planning for Startup (High: >=5.6, Low: <5.6)	0.067	8	0.154	11	0.122	10	9.67	9
8	Timely Engineering (High: >=8.7, Low: <8.7)	0.216	2	1.465	2	0.577	4	2.67	2
9	Accurate Engineering (High: >=7.2, Low: <7.2)	0.098	7	0.789	7	0.356	7	7.00	7
10	Percent Design Completion at AFE (High: >=4.1, Low: <4.1)	0.050	9	0.403	9	0.118	11	9.67	9
11	Percent Design Completion prior to Construction (High: >=3.2, Low: <3.2)	0.048	10	0.417	8	0.166	8	8.67	8
12	Alliance (High: >=7.2, Low: <7.2)	0.008	11	0.268	10	0.135	9	10.00	11

3.5.8 ANALYSIS ON THE COMBINED EFFECTS OF CRITICAL PROJECT MANAGEMENT ATTRIBUTES ON PROJECT PERFORMANCE OUTCOMES

The fourth research question, "What are the combined effects of critical project management attributes on project performance outcomes?" was examined by two composite indicators: 1) number of the critical project management attributes implemented at high-level and 2) composite implementation score of the critical project management attributes. The two composite indicators were used to show the combined level of effort put into the critical project management attributes. Then, analyses were conducted to examine the relationships between project performance outcomes and the two composite indicators.

The first indicator is the count of project management attributes implemented at high-level. The implementation level of the critical project management attributes was categorized into high-level implementation or low-level implementation by the contingency table analysis, as described in Section 3.5.4. Accordingly, the number of critical project management attributes implemented at high-level was counted for each project. Then, the relationship between the number of critical project management attributes and project performance outcomes was examined by regression analysis methods. Table 3.9 shows an example of how the number of critical project management attributes is counted for each project.

Table 3.9: Example of Number of Critical Project Management Attributes

Project ID	Performance Outcome: Business Performance		Project Management Attributes: Timely Eng. Deliverables			Alignment			Change Management			Number of Critical Project Management Attributes
	Worse	Better	Metric Value	Implementation Category: Low	Implementation Category: High	Metric Value	Implementation Category: Low	Implementation Category: High	Metric Value	Implementation Category: Low	Implementation Category: High	
	>Median	<=Median		<4.7	>=4.7		<7.7	>=7.7		<4.3	>=4.3	
Project A	Better		4.0	Low		8.6	High		9.2	High		2
Project B	Better		5.2	High		3.7	Low		4.1	Low		1
Project C	Worse		7.2	High		7.5	High		3.2	Low		2
Project D	Worse		8.8	High		7.9	High		7.6	High		3
≀	≀		≀	≀		≀	≀		≀	≀		≀

Table 3.10: Example of Composite Implementation Score

f(y) = 0.1 + 1.9 x (Timely Engineering Deliverables) + 1.4 x (Alignment) + 1.1 x (Change Management)

Project ID	Performance Outcome (y): Business Performance Category		Project Management Attributes: Timely Engin. Deliverable				Alignment				Change Management				Composite Implementation Score (X)	
	Worse	Better	Metric Value	Implementation Category: Low	Implementation Category: High	Score	Metric Value	Implementation Category: Low	Implementation Category: High	Score	Metric Value	Implementation Category: Low	Implementation Category: High	Score		
	>Median	<=Median		<7.7	>=7.7			<5.7	>=5.7			<6.3	>=6.3			
Project A	Better		4.0	Low		0	8.6	High		1.4	9.2	High		1.1	5.68	=(0+1.4+1.1) ÷ 4.4 x 10
Project B	Better		5.2	High		1.9	3.7	Low		0	4.1	Low		0	4.32	=(1.9+0+0) ÷ 4.4 x 10
Project C	Worse		7.2	High		1.9	7.5	High		1.4	3.2	Low		1.1	7.50	=(1.9+1.4+0) ÷ 4.4 x 10
Project D	Worse		8.8	High		1.9	7.9	High		1.4	7.6	High		1.1	10.00	=(1.9+1.4+1.1) ÷ 4.4 x 10
≀	≀		≀	≀			≀	≀			≀	≀			≀	

The second indictor is a composite implementation score which considers the relative importance of the critical project management attributes. For each project, composite implementation scores were calculated by the implementation level of the critical project management attributes and their coefficients as follows:

$$\text{Composite Implementation Score} = \frac{\sum_{i=1}^{n} IL_i \times Coefficient_i}{\sum_{i=1}^{n} Coefficient_i} \text{X} 10$$

where IL_i – Implementation Level of the i^{th} Critical Project Management Attribute;
$Coefficient_i$ – Coefficient of the i^{th} Critical Project Management Attribute;
n – Number of Critical Project Management Attributes

Since three sets of coefficients derived from three regression methods generated three composite implementation scores, the average of the three composite implementation scores was given to each project. The rationale for using the average of three composite implementation scores was to calculate composite implementation scores for each project more objectively. Table 3.10 shows an example of how the composite implementation score for each project is calculated by using the coefficients derived from a multiple regression method.

Both the number of the critical project management attributes implemented at high-level and the composite implementation score of the critical project management attributes can be considered as an index indicating the level of effort put into the implementation of the critical project management attributes. In this context, OLS and logit were conducted to examine the combined effects of project management attributes on project performance outcomes. The next chapter discusses the interpretation of the results of the regression analyses.

CHAPTER 4: RESUTS

This chapter describes the analysis results regarding the relationships between project management attributes and the performance outcomes. The chapter is divided into Section 4.1 Owner Projects and Section 4.2 Contractor Projects. Each of them consists of subchapters focusing on cost, schedule, safety, quality, or business performance.

4.1 OWNER PROJECTS

4.1.1 COST PERFORMANCE

Cost performance was evaluated by using the cost growth metric {(Actual Total Project Cost – Initial Planned Project Cost) / Initial Planned Project Cost}. This metric evaluates an actual cost result compared with an original cost plan. As described in Section 3.5.3, the cost growth metric was preprocessed and categorized into two performance categories. Projects whose cost growth metric was equal to or less than zero were categorized into the better performance category, while projects whose cost growth metric was greater than zero were categorized into the worse performance category (Table 4.1).

Table 4.1: Cost Growth Performance Category

	Better Performance Category	Worse Performance Category
Cost Growth	< = 0	> 0

Identification of Minimum Implementation Levels for Project Management Attributes

For better cost growth performance, Table 4.2 shows the minimum implementation levels for 19 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better cost growth performance than projects implemented below the minimum level. By using the chi-square test and the Fisher's exact test, whether there is a statistically significant difference in the probabilities of better cost growth performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better cost growth performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.2: Minimum Implementation Level for Project Management Attributes for Better Cost Growth Performance

	Project Management Attribute	Minimum Level	Significance of Better Cost Growth Performance
1	PDRI	8.7	*
2	FEP	7.7	*
3	Alignment	5.7	*
4	Partnering	6.3	*
5	Team Building	9.3	
6	Change Management	8.1	*
7	PDCS	8.3	*
8	Constructability	8.0	
9	Project Risk Analysis	8.6	
10	Planning for Startup	5.6	*
11	Zero Accident Technique	6.7	
12	Timely Engineering Deliverables	4.3	*
13	Accurate Engineering Deliverables	7.2	*
14	Percent Design Completion at AFE	4.1	*
15	Percent Design Completion prior to Construction	3.2	*
16	Alliance	7.2	*
17	Budget Accuracy	6.1	
18	Fast Track (Yes or No)	Yes	
19	Modularization	0.1	

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to cost growth performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for cost growth performance. As shown in Table 4.3, 12 critical project management attributes for cost growth performance were identified, including PDRI, FEP, alignment, partnering, change management, PDCS, planning for startup, timely engineering deliverables, accurate engineering deliverables, percent design completion at AFE, percent design completion prior to construction, and alliance.

Table 4.3: Critical Project Management Attributes for Cost Growth Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI	*	*	*	*
2	FEP	*	*	*	*
3	Alignment	*	*	*	*
4	Partnering	*	*	*	*
5	Team Building				
6	Change Management	*	*	*	*
7	PDCS	*	*	*	*
8	Constructability				
9	Project Risk Assessment				
10	Planning for Startup	*	*	*	*
11	Zero Accident Technique				
12	Timely Engineering Deliverables	*	*	*	*
13	Accurate Engineering Deliverables	*	*	*	*
14	Percent Design Completion at AFE	*	*	*	*
15	Percent Design Completion prior to Construction	*	*	*	*
16	Alliance	*	*	*	*
17	Budget Accuracy				
18	Fast-track				
19	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the 12 critical project management attributes for better cost growth performance, as discussed in Section 3.5.7. For the 12 critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better cost growth performance. The ranks of the three methods were averaged to generate an overall relative importance of the 12 critical project management attributes, as shown in Table 4.4.

Table 4.4: Relative Importance of Critical Project Management Attributes for Better Cost Growth Performance

	Project Management Attribute (High- or Low Level Implementation)	Linear		Logit		Probit		Overall	
		Coeff.	Rank	Coeff.	Rank	Coeff.	Rank	Rank Average	Rank
1	PDRI (High: >=8.7, Low: <8.7)	0.263	1	3.257	1	1.148	1	1.00	1
2	Timely Engineering (High: >=4.3 Low: <4.3)	0.216	2	1.465	2	0.577	4	2.67	2
3	FEP (High: >=7.7, Low: <7.7)	0.186	4	1.427	3	0.684	2	3.00	3
4	Partnering (High: >=6.3, Low: <6.3)	0.208	3	1.339	4	0.618	3	3.00	4
5	Alignment (High: >=5.7, Low: <5.7)	0.150	5	0.910	5	0.393	5	5.00	5
6	Change Management (High: >=8.1, Low: <8.1)	0.120	6	0.903	6	0.361	6	6.00	6
7	Accurate Engineering (High: >=7.2, Low: <7.2)	0.098	7	0.789	7	0.356	7	7.00	7
8	Percent Design Completion prior to Construction (High: >=3.2, Low: <3.2)	0.048	10	0.417	8	0.166	8	8.67	8
9	Planning for Startup (High: >=5.6, Low: <5.6)	0.067	8	0.154	11	0.122	10	9.67	9
10	Percent Design Completion at AFE (High: >=4.1, Low: <4.1)	0.050	9	0.403	9	0.118	11	9.67	9
11	Alliance (High: >=7.2, Low: <7.2)	0.008	11	0.268	10	0.135	9	10.00	11
12	Project Delivery Contract Strategy (High: >=8.3, Low: <8.3)	-0.004	12	-0.011	12	-0.067	12	12.00	12

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the PDRI attribute ranked first, which indicates that the implementation of this attribute with a score of 8.7 or above was the most important project management attribute for better cost growth performance. However, it should be noted that the PDRI attribute might not be the most important project management attribute when implemented with less than 8.7.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better cost growth performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better cost growth performance. Nonetheless, since all of the 12 critical project management attributes were significantly related to cost growth performance, the implementation of them all would be the best way to expect higher probability of better cost growth performance.

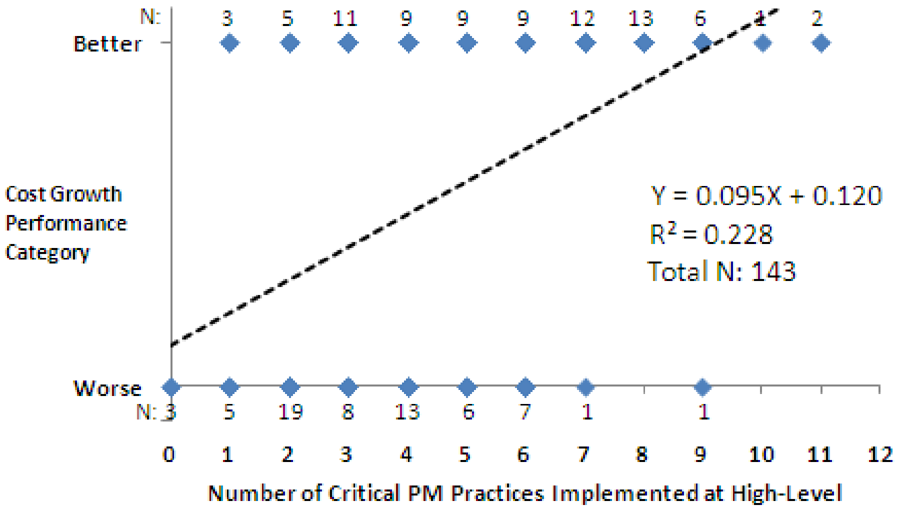
Analysis of the Combined Effects of Critical Project Management Attributes

The effects of combined critical project management attributes on cost growth performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the 12 critical project management attributes for cost growth performance were grouped into low-level or high-level as shown in Table 4.4, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and cost growth performance was examined. Figure 4.1 and Figure 4.2 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.1 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of cost growth performance (B=0.095, P-value=0.000). The fitted regression equation (Y = 0.095X + 0.120) also indicated a good model fit (F=41.664, P-value =0.000) and correctly classified 69.9% of 143 owner projects for the cost growth performance category. The equation implies that owner projects could achieve better cost growth performance (Y>0.5) when they executed five or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.095	.015	.478	6.455	.000
(Constant)	.120	.077		1.548	.124

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	8.039	1	8.039	41.664	0.000
Residual	27.206	141	.193		
Total	35.245	142			

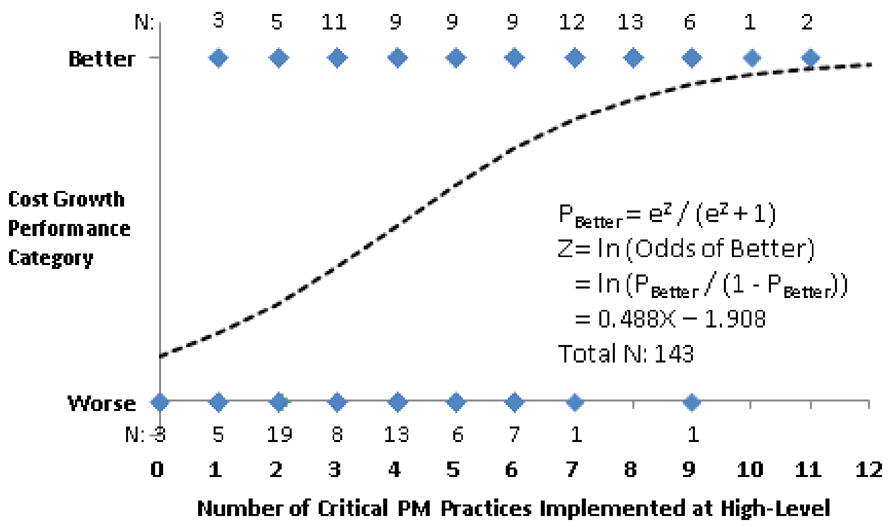
R	R Square	Adjusted R Square
0.478	.228	.223

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	48	15	76.2
		Better	28	52	65.0
	Overall Percentage				69.9

Figure 4.1: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Cost Growth Performance

The logit regression analysis results provided in Figure 4.2 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of cost growth performance (B=0.488, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 67.1% of 143 owner projects were correctly classified for the cost growth performance category. The fitted logit regression equation ($P_{Better} = e^{(0.488X-1.908)} / (e^{(0.488X-1.908)}+1)$) implies that the odds of better cost growth performance were increased by a multiplicative factor of 1.628 ($=e^{(0.488)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that owner projects could achieve better cost growth performance (Y>0.5) when they executed four or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.488	.094	26.666	1	.000	1.628
(Constant)	-1.908	.439	18.879	1	.000	.148

Model Fit

	Chi-square	df	Sig.
Hosmer and Lemeshow Test	10.502	7	.162

Cox & Snell R Square	Nagelkerke R Square
.226	.303

Classification Table

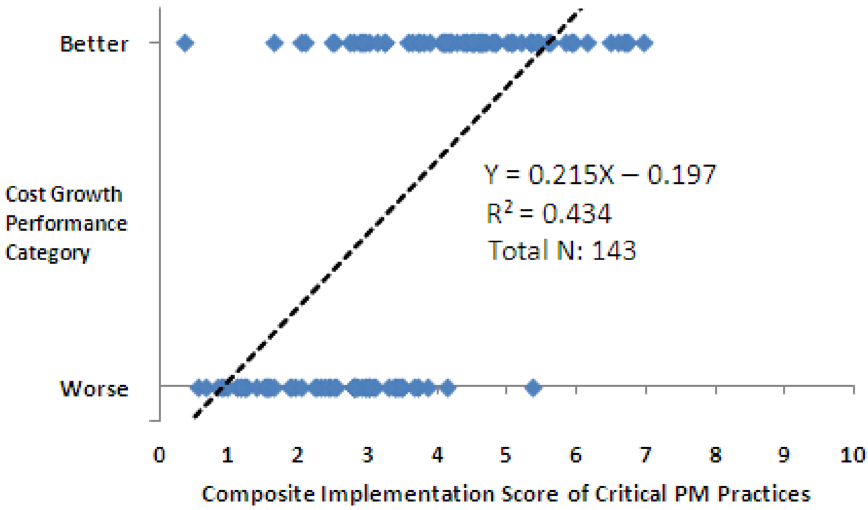
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	35	28	55.6
		Better	19	61	76.3
	Overall Percentage				67.1

Figure 4.2: Logit Regression Analysis Results for Relationship between Number of Critical project management Attributes Implemented at High-Level and Cost Growth Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on cost growth performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.3 and 4.4 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.3 shows that the composite implementation score was a significant predictor of cost growth performance (B=0.215, P-value=0.000). The fitted regression equation ($Y = 0.215X - 0.197$) also indicated a good model fit (F=108.073, P-value =0.000) and correctly classified 79.7% of 143 owner projects for the cost growth performance category. The equation implies that that owner projects could achieve better cost growth performance ($Y>0.5$) when their composite implementation score was equal or more than 3.25.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.215	.021	.659	10.396	.000
(Constant)	-.197	.079		-2.489	.014

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	15.293	1	15.293	108.073	0.000
Residual	19.952	141	.142		
Total	35.245	142			

R	R Square	Adjusted R Square
0.659	.434	.430

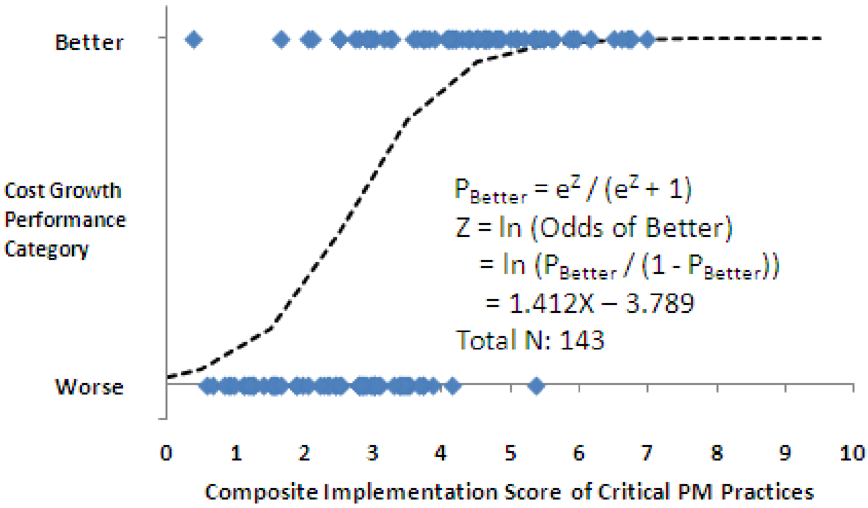
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	49	14	77.8
		Better	15	65	81.3
	Overall Percentage				79.7

Figure 4.3: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Cost Growth Performance

The logit regression analysis results provided in Figure 4.4 also indicates that the composite implementation score was a highly significant predictor of cost growth performance (B=1.412, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 80.4% of 143 owner projects were correctly classified for the cost growth performance category. The fitted regression equation ($P_{Better} = e^{(1.412X-3.789)} / (e^{(1.412X-3.789)}+1)$ implies that the odds of better cost growth performance were increased by a multiplicative factor of 4.106 (=$e^{(1.412)}$) for every one point increase in the composite implementation score. It also indicates that owner projects could achieve better cost growth performance (Y>0.5) when the composite implementation score of the critical project management attributes were 2.68 or above.

Using OLS regression and logit regression, cost growth performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with cost growth performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that cost growth performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	1.412	.232	37.197	1	.000	4.106
(Constant)	-3.789	.684	30.689	1	.000	.023

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	8.756	8	.363

Cox & Snell R Square	Nagelkerke R Square
.424	.568

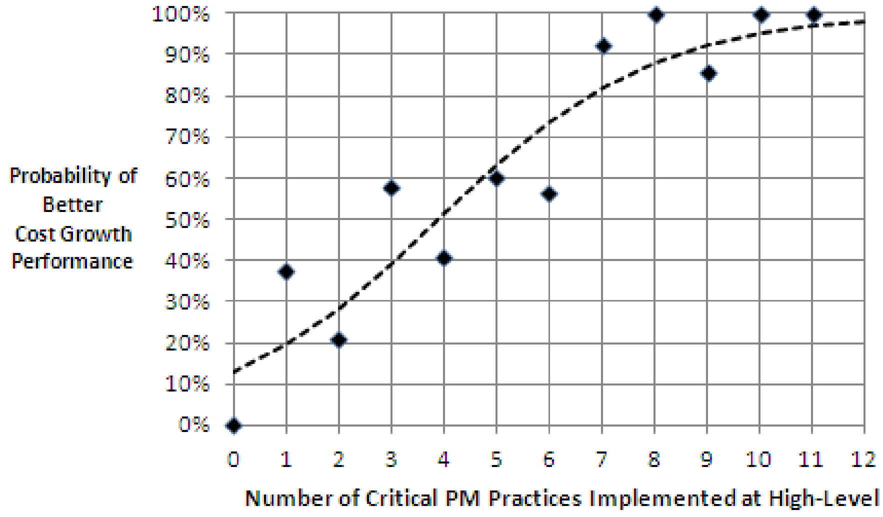
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	49	14	77.8
		Better	14	66	82.5
	Overall Percentage				80.4

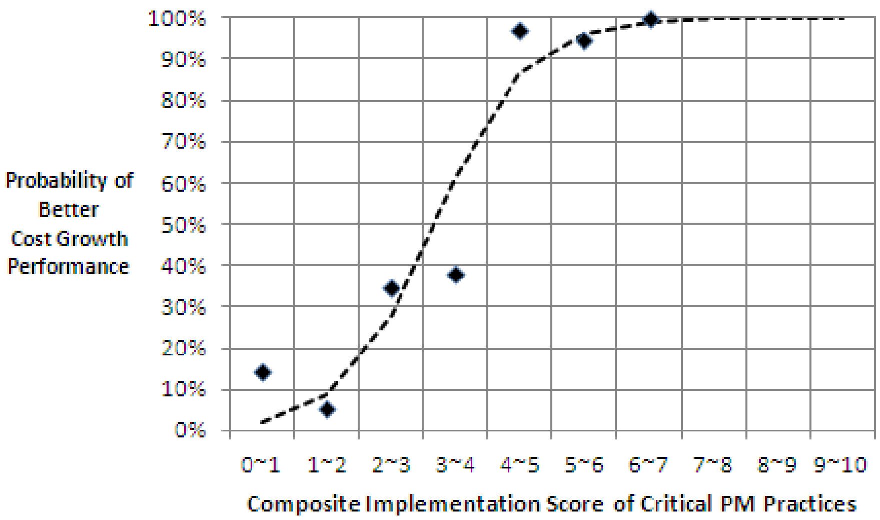
Figure 4.4: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Cost Growth Performance

Figure 4.5 represents changes in the probability of better cost growth performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better cost growth performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better cost growth performance. It can be suggested to implement seven or more of the critical project management attributes implemented at high-level and make the composite implementation score over four because projects showed a higher probability of better cost growth performance in such implementation.

To sum up, this chapter identified 12 critical project management attributes significantly related to cost growth performance when they were implemented with more than a certain level of effort (Table 4.2 and Table 4.3). The regression analyses arranged the 12 critical project management attributes into their order of relative importance (Table 4.4). The combined effects of the 12 project management attributes on cost growth performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.1 ~ Figure 4.5).



Number of Projects	Better	0	3	5	11	9	9	9	12	13	6	1	2	0
	Worse	3	5	19	8	13	6	7	1	0	1	0	0	0
	Total	3	8	24	19	22	15	16	13	13	7	1	2	0



Number of Projects	Better	1	1	10	11	32	18	7	0	0	0
	Worse	6	18	19	18	1	1	0	0	0	0
	Total	7	19	29	29	33	19	7	0	0	0

Figure 4.5: Probability of Better Cost Growth Performance by Two Indicators

4.1.2 SCHEDULE PERFORMANCE

Schedule performance was evaluated by using the schedule growth metric {(Actual Total Project Duration – Initial Planned Project Duration) / Initial Planned Project Duration}. This metric evaluates an actual schedule result compared with an original schedule plan. As described in Section 3.5.3, the schedule growth metric was preprocessed and categorized into two performance categories. Projects whose schedule growth metric was equal to or less than zero were categorized into the better performance category, while projects whose schedule growth metric was greater than zero were categorized into the worse performance category (Table 4.5).

Table 4.5: Schedule Growth Performance Category

	Better Performance Category	Worse Performance Category
Schedule Growth	< = 0	> 0

Identification of Minimum Implementation Levels for Project Management Attributes

For better schedule growth performance, Table 4.6 shows the minimum implementation levels for 19 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better schedule growth performance than projects implemented below the minimum level. By using the chi-square test and the Fisher's exact test, whether there is a statistically significant difference in the probabilities of better schedule growth performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better schedule growth performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.6: Minimum Implementation Level for Project Management Attributes for Better Schedule Growth Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Schedule Growth Performance
1	PDRI	6.7	
2	FEP	7.5	*
3	Alignment	6.0	*
4	Partnering	6.0	*
5	Team Building	6.7	*
6	Change Management	6.2	*
7	PDCS	6.2	*
8	Constructability	7.8	
9	Project Risk Analysis	4.4	*
10	Planning for Startup	7.0	*
11	Zero Accident Technique	5.4	
12	Timely Engineering Deliverables	7.2	
13	Accurate Engineering Deliverables	7.2	*
14	Percent Design Completion at AFE	0.8	
15	Percent Design Completion prior to construction	3.2	*
16	Alliance	5.8	
17	Budget Accuracy	6.1	
18	Fast Track (Yes or No)	Yes	
19	Modularization	3.1	

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to schedule growth performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for schedule growth performance. As shown in Table 4.7, 12 critical project management attributes for schedule growth performance were identified, including FEP, alignment, partnering, team building, change management, project delivery and contract strategy, project risk analysis, planning for startup, timely engineering deliverables, accurate engineering deliverables, percent design completion prior to construction, and alliance.

Table 4.7: Critical Project Management Attributes for Schedule Growth Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI				
2	FEP	*	*	*	*
3	Alignment	*	*	*	*
4	Partnering	*	*	*	*
5	Team Building	*	*	*	*
6	Change Management	*	*	*	*
7	PDCS	*	*	*	*
8	Constructability				
9	Project Risk Assessment	*	*	*	*
10	Planning for Startup	*	*	*	*
11	Zero Accident Technique				
12	Timely Engineering Deliverables	*	*	*	*
13	Accurate Engineering Deliverables	*	*	*	*
14	Percent Design Completion at AFE				
15	Percent Design Completion prior to Construction	*	*	*	*
16	Alliance	*	*	*	*
17	Budget Accuracy				
18	Fast-track				
19	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the 12 critical project management attributes for better schedule growth performance, as discussed in Section 3.5.7. For the 12 critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better schedule growth performance. The ranks of the three methods were averaged to generate an overall relative importance of the 12 critical project management attributes, as shown in Table 4.8.

Table 4.8: Overall Relative Importance of Critical Project Management Attributes for Schedule Growth Performance

	Project Management Attribute (High- or Low Level Implementation)	Linear		Logit		Probit		Overall	
		Coeff.	Rank	Coeff.	Rank	Coeff.	Rank	Rank Average	Rank
1	Accurate Engineering Deliverables (High: >=5.8, Low: <5.8)	0.200	1	1.540	1	0.903	1	1.0	1
2	Planning for Startup (High: >=7.0, Low: <7.0)	0.180	2	1.251	2	0.767	2	2.00	2
3	Percent Design Completion prior to Construction (High: >=3.2, Low: <3.2)	0.148	3	1.134	4	0.653	3	3.33	3
4	Project Risk Assessment (High: >=4.4, Low: <4.4)	0.134	4	0.898	5	0.490	4	4.33	4
5	Change Management (High: >=6.2, Low: <6.2)	0.050	8	1.199	3	0.480	5	5.33	5
6	Partnering (High: >=6.0, Low: <6.0)	0.103	7	0.687	6	0.457	6	6.33	6
7	Team Building (High: >=6.7, Low: <6.7)	0.132	5	0.526	8	0.307	7	6.67	7
8	Project Delivery and Contract Strategy (High: >=6.2, Low: <6.2)	0.114	6	0.567	7	0.306	8	7.00	8
9	Alliance (High: >=5.8, Low: <5.8)	0.041	9	0.086	9	0.030	10	9.33	9
10	Timely Engineering (High: >=7.2 Low: <7.2)	0.014	11	0.044	11	0.065	9	10.33	10
11	Alignment (High: >=6.0, Low: <6.0)	-0.027	12	0.051	10	0.026	11	11.00	11
12	FEP (High: >=7.5, Low: <7.5)	0.027	10	-0.088	12	-0.064	12	11.33	12

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the accurate engineering deliverables attribute ranked first, which indicates that the implementation of this attribute with a score of 5.8 or above was the most important project management attribute for better schedule growth performance. However, it should be noted that the accurate engineering deliverables attribute might not be the most important project management attribute when implemented with less than 5.8.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better schedule growth performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better schedule growth performance. Nonetheless, since all of the 12 critical project management attributes were significantly related to schedule growth performance, the implementation of them all would be the best way to expect higher probability of better schedule growth performance.

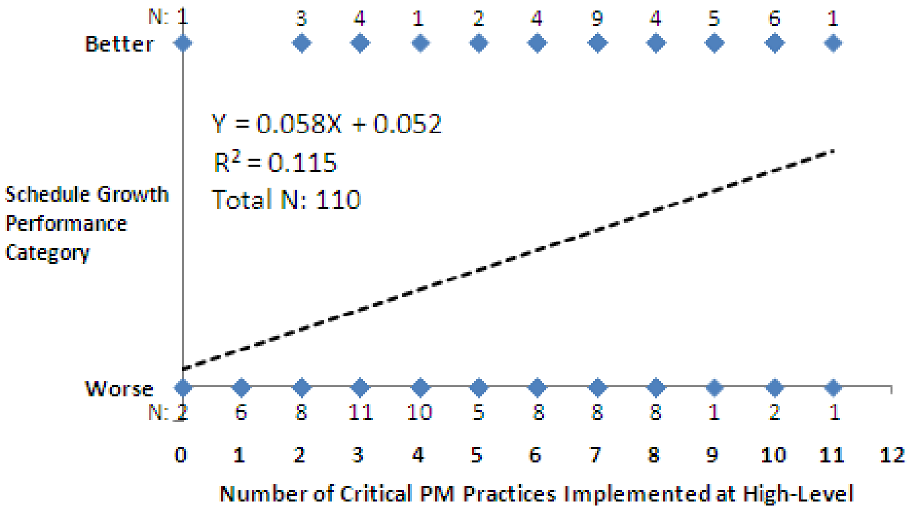
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on schedule growth performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the 12 critical project management attributes for schedule growth performance were divided into low-level or high-level as shown in Table 4.8, the number of the critical project management attributes with high-level implementation could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and schedule growth performance was examined. Figure 4.6 and Figure 4.7 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.6 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of schedule growth performance (B=0.058, P-value=0.000). The fitted regression equation ($Y = 0.058X + 0.052$) also indicated a good model fit (F=13.986, P-value =0.000) and correctly classified 67.3% of 110 owner projects for the schedule growth performance category. The equation implies that owner projects could achieve better schedule growth performance ($Y>0.5$) when they executed eight or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.058	.015	.339	3.740	.000
(Constant)	.052	.094		.552	.582

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.918	1	2.918	13.986	0.000
Residual	22.536	108	.209		
Total	25.455	109			

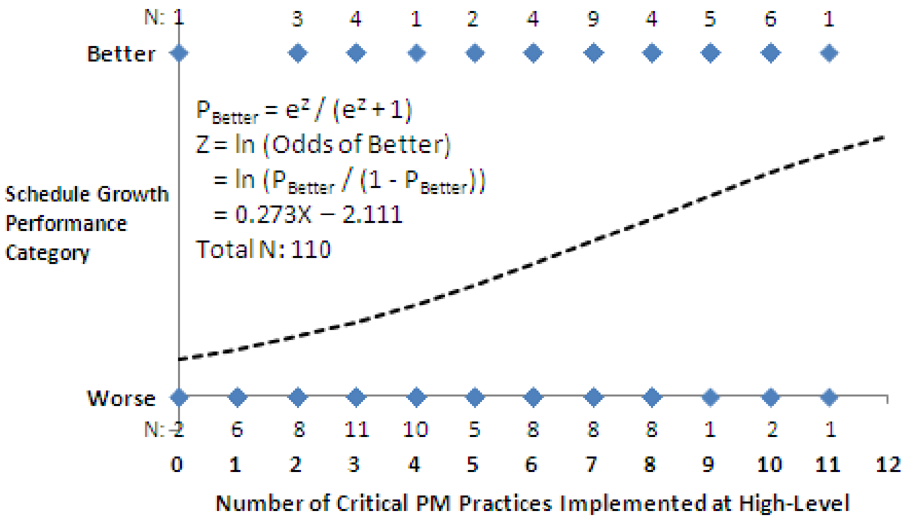
R	R Square	Adjusted R Square
0.339	.115	.106

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	58	12	82.9
		Better	24	16	40.0
	Overall Percentage				67.3

Figure 4.6: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Cost Growth Performance

The logit regression analysis results provided in Figure 4.7 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of schedule growth performance (B=0.273, P-value=0.001). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 67.3% of 110 owner projects were correctly classified for the schedule growth performance category. The fitted regression equation ($P_{Better} = e^{(0.273X-2.111)} / (e^{(0.273X-2.111)}+1)$) implies that the odds of better schedule growth performance were increased by a multiplicative factor of 1.313 (=$e^{(0.273)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that owner projects could achieve better schedule growth performance (Y>0.5) when they executed eight or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.273	.080	11.511	1	.001	1.313
(Constant)	-2.111	.523	16.318	1	.000	.121

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	5.922	7	.549

Cox & Snell R Square	Nagelkerke R Square
.113	.155

Classification Table

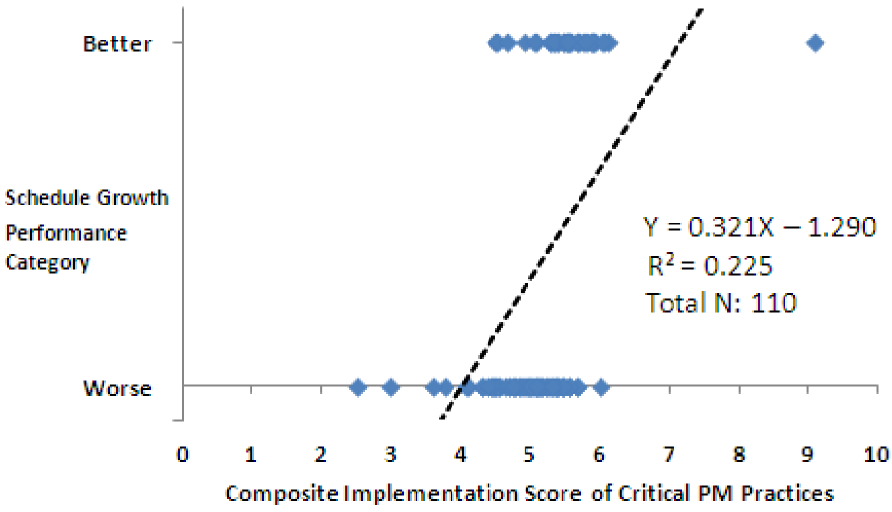
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	58	12	82.9
		Better	24	16	40.0
	Overall Percentage				67.3

Figure 4.7: Logit Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Schedule Growth Performance

A Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on schedule growth performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.8 and 4.9 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.8 shows that the composite implementation score was a significant predictor of schedule growth performance (B=0.249, P-value=0.000). The fitted regression equation (Y = 0.321X − 1.290) also indicated a good model fit (F=31.379, P-value=0.000) and correctly classified 76.4% of 110 owner projects for the schedule growth performance category. The equation implies that that owner projects could achieve better schedule growth performance (Y>0.5) when their composite implementation score was equal or more than 5.58.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.321	.057	.474	5.602	.000
(Constant)	-1.290	.298		-4.329	.000

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.731	1	5.731	31.379	0.000
Residual	19.724	108	.183		
Total	25.455	109			

R	R Square	Adjusted R Square
0.474	.225	.218

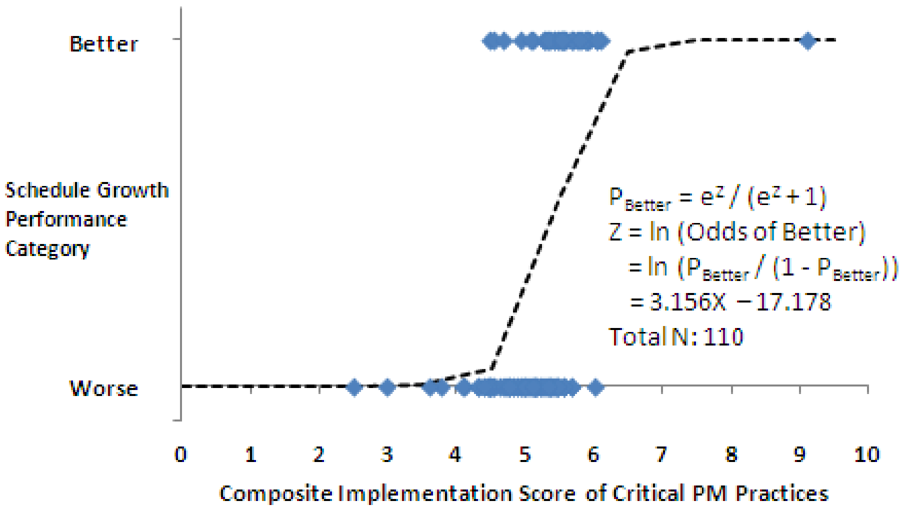
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	67	3	95.7
		Better	23	17	42.5
	Overall Percentage				76.4

Figure 4.8: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Schedule Growth Performance

The logit regression analysis results provided in Figure 4.9 also indicates that the composite implementation score was a highly significant predictor of schedule growth performance (B=3.156, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 77.3% of 110 owner projects were correctly classified for the schedule growth performance category. The fitted regression equation ($P_{Better} = e^{(3.156X-17.178)}/ (e^{(3.156X-17.178)}+1)$) implies that the odds of better schedule growth performance were increased by a multiplicative factor of 23.466 ($=e^{(3.156)}$) for every one point increase in the composite implementation score. It also indicates that owner projects could achieve better schedule growth performance ($Y>0.5$) when the composite implementation score of the critical project management attributes were 5.44 or above.

Using OLS regression and logit regression, schedule growth performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with schedule growth performance. The OLS and logit regression models also showed a good model fit and classification ability. Therefore, it is implied that schedule growth performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	3.156	.688	21.026	1	.000	23.466
(Constant)	-17.178	3.684	21.736	1	.000	.000

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	9.678	8	.288

Cox & Snell R Square	Nagelkerke R Square
.296	.405

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	59	11	84.3
		Better	14	26	65.0
	Overall Percentage				77.3

Figure 4.9: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Schedule Growth Performance

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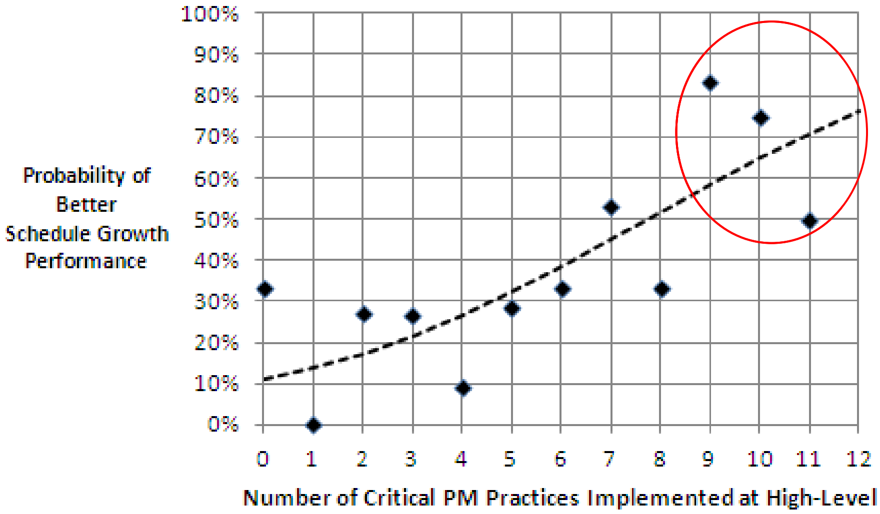
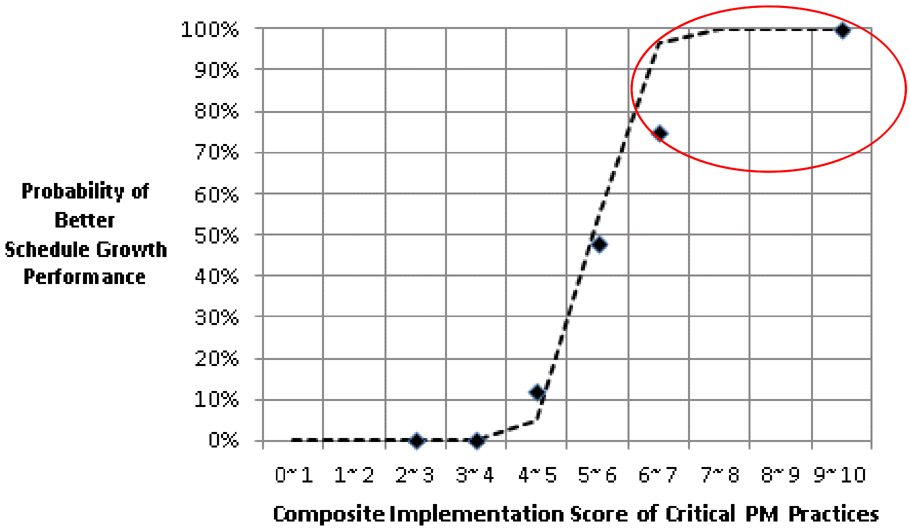
Figure 4.10 represents changes in the probability of better schedule growth performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better schedule growth performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better schedule growth performance. It can be suggested to implement nine or more of the critical project management attributes implemented at high-level and make the composite implementation score over six because projects showed a higher probability of better cost growth performance in such implementation.

To sum up, this chapter identified 12 project management attributes significantly related to schedule growth performance when they were implemented with more than a certain level of effort (Table 4.7 and Table 4.8). The regression analyses arranged the 12 project management attributes into their order of relative importance (Table 4.9). The combined effects of the 12 project management attributes on schedule growth performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.6 ~ Figure 4.10).



Number of Projects														
	Better	1	0	3	4	1	2	4	9	4	5	6	1	0
	Worse	2	6	8	11	10	5	8	8	8	1	2	1	0
	Total	3	6	11	15	11	7	12	17	12	6	8	2	0



Number of Projects											
	Better	0	0	0	0	4	32	3	0	0	1
	Worse	0	0	2	2	30	35	1	0	0	0
	Total	0	0	2	2	34	67	4	0	0	1

Figure 4.10: Probability of Better Schedule Growth Performance by Two Indicators

4.1.3 SAFETY PERFORMANCE

Safety performance was evaluated by a survey question asking the level of satisfaction of safety goals. The question used a seven point Likert-scale in which one means “not at all successful” and seven means “extremely successful”. As described in Section 3.5.3, the level of satisfaction of safety goals was categorized into two performance categories. Projects whose level of satisfaction of safety goals was seven were categorized into the better performance category, while projects whose level of satisfaction of safety goals was six or below were categorized into the worse performance category (Table 4.9).

Table 4.9: Safety Performance Category

	Better Performance Category	Worse Performance Category
Safety Performance	Extremely Successful	Other

Identification of Minimum Implementation Levels for Project Management Attributes

For better safety performance, Table 4.10 shows the minimum implementation levels for 19 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better safety performance than projects implemented below the minimum level. By using the chi-square test and the Fisher’s exact test, whether there is a statistically significant difference in the probabilities of better safety performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better safety performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.10: Minimum Implementation Level for Project Management Attributes for Better Safety Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Safety Performance
1	PDRI	8.0	
2	FEP	9.1	*
3	Alignment	7.2	*
4	Partnering	7.0	*
5	Team Building	9.3	
6	Change Management	8.6	
7	PDCS	8.8	*
8	Constructability	7.8	*
9	Project Risk Analysis	7.4	*
10	Planning for Startup	6.9	*
11	Zero Accident Technique	6.4	*
12	Timely Engineering Deliverables	8.6	*
13	Accurate Engineering Deliverables	4.3	
14	Percent Design Completion at AFE	4.1	
15	Percent Design Completion prior to construction	2.6	
16	Alliance	8.6	
17	Budget Accuracy	8.1	
18	Fast Track (Yes or No)	Yes	
19	Modularization	2.1	*

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to safety performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for safety performance. As shown in Table 4.11, 10 critical project management attributes for safety performance were identified, including FEP, alignment, partnering, team building, project delivery and contract strategy, constructability, project risk analysis, planning for startup, zero accident technique, timely engineering deliverables, and modularization.

Table 4.11: Critical Project Management Attributes for Safety Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI				
2	FEP	*	*	*	*
3	Alignment	*	*	*	*
4	Partnering	*	*	*	*
5	Team Building				
6	Change Management				
7	PDCS	*	*	*	*
8	Constructability	*	*	*	*
9	Project Risk Assessment	*	*	*	*
10	Planning for Startup	*	*	*	*
11	Zero Accident Technique	*	*	*	*
12	Timely Engineering Deliverables	*	*	*	*
13	Accurate Engineering Deliverables				
14	Percent Design Completion at AFE				
15	Percent Design Completion prior to Construction				
16	Alliance				
17	Budget Accuracy				
18	Fast-track				
19	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the 10 critical project management attributes for better safety performance, as discussed in Section 3.5.7. For the 10 critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better safety performance. The ranks of the three methods were averaged to generate an overall relative importance of the 10 critical project management attributes, as shown in Table 4.12.

Table 4.12: Relative Importance of Critical Project Management Attributes for Better Safety Performance

	Project management Attribute (High- or Low-Level Implementation Group)	Linear		Logit		Probit		Overall	
		Coef	Rank	Coef	Rank	Coef	Rank	Rank Average	Rank
1	FEP (High: >=9.1, Low: <9.1)	0.287	2	2.142	1	1.232	1	1.33	1
2	Project Risk Analysis (High: >=7.4, Low: <7.4)	0.311	1	1.816	3	1.105	2	2.00	2
3	Constructability (High: >=7.8, Low: <7.8)	0.228	3	1.831	2	0.973	3	2.67	3
4	Project Delivery Contract Strategy (High: >=8.8, Low: <8.8)	0.164	5	1.319	4	0.866	4	4.33	4
5	Timely Engineering Deliverables (High: >=8.6, Low: <8.6)	0.224	4	1.314	5	0.786	5	4.67	5
6	Modularization (High: >=2.1, Low: <2.1)	0.159	6	1.162	6	0.714	6	6.00	6
7	Zero Accident Technique (High: >=6.4, Low: <6.4)	0.129	7	0.950	7	0.571	7	7.00	7
8	Partnering (High: >=7.0, Low: <7.0)	0.062	9	0.550	8	0.407	8	8.33	8
9	Planning for Startup (High: >=6.9, Low: <6.9)	0.100	8	0.373	9	0.228	9	8.77	9
10	Alignment (High: >=7.2, Low: <7.2)	-0.041	10	-0.470	10	-0.320	10	10.0	10

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the FEP attribute ranked first, which indicates that the implementation of this attribute with a score of 9.1 or above was the most important project management attribute for better safety performance. However, it should be noted that the FEP attribute might not be the most important project management attribute when implemented with less than 9.1.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better safety performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better safety performance. Nonetheless, since all of the 10 critical project management attributes were significantly related to safety performance, the implementation of them all would be the best way to expect higher probability of better safety performance.

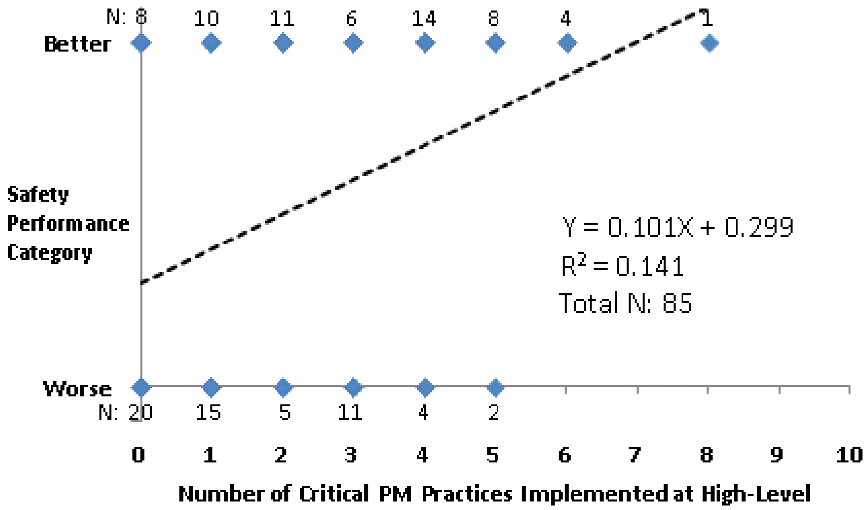
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on safety performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the 10 critical project management attributes for safety performance were divided into low-level or high-level as shown in Table 4.12, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and safety performance was examined. Figure 4.11 and Figure 4.12 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.11 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of safety performance (B=0.101, P-value=0.000). The fitted regression equation ($Y = 0.101X + 0.299$) also indicated a good model fit (F=19.208, P-value =0.000) and correctly classified 66.4% of 85 owner projects for the safety performance category. The equation implies that owner projects could achieve better safety performance ($Y>0.5$) when they executed two or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
X	.101	.023	.376	4.383	.000
(Constant)	.299	.066		4.503	.000

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.188	1	4.188	19.208	0.000
Residual	25.510	117	.218		
Total	29.697	118			

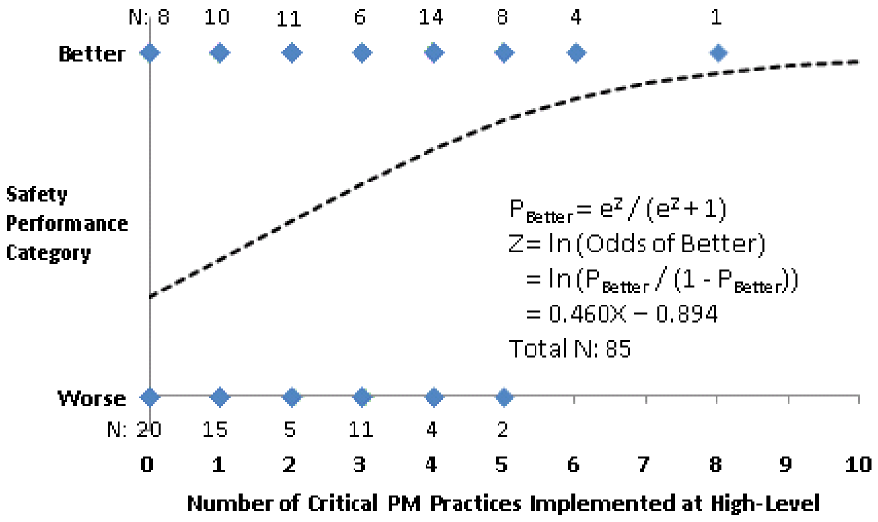
R	R Square	Adjusted R Square
0.376	.141	.134

Classification Table

			Predicted: Performance Category Worse	Predicted: Performance Category Better	Predicted: Percentage Correct
Observed	Performance Category	Worse	35	22	61.4
		Better	18	44	71.0
	Overall Percentage				66.4

Figure 4.11: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Safety Performance

The logit regression analysis results provided in Figure 4.12 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of safety performance (B=0.460, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 66.4% of 85 owner projects were correctly classified for the safety performance category. The fitted logit regression equation ($P_{Better} = e^{(0.460X-0.894)} / (e^{(0.460X-0.894)}+1)$) implies that the odds of better safety performance were increased by a multiplicative factor of 1.585 (=$e^{(0.460)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that owner projects could achieve better safety performance (Y>0.5) when they executed two or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.460	.119	15.074	1.000	.000	1.585
(Constant)	-.894	.311	8.244	1.000	.004	.409

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	7.660	4	.105

Cox & Snell R Square	Nagelkerke R Square
.140	.187

Classification Table

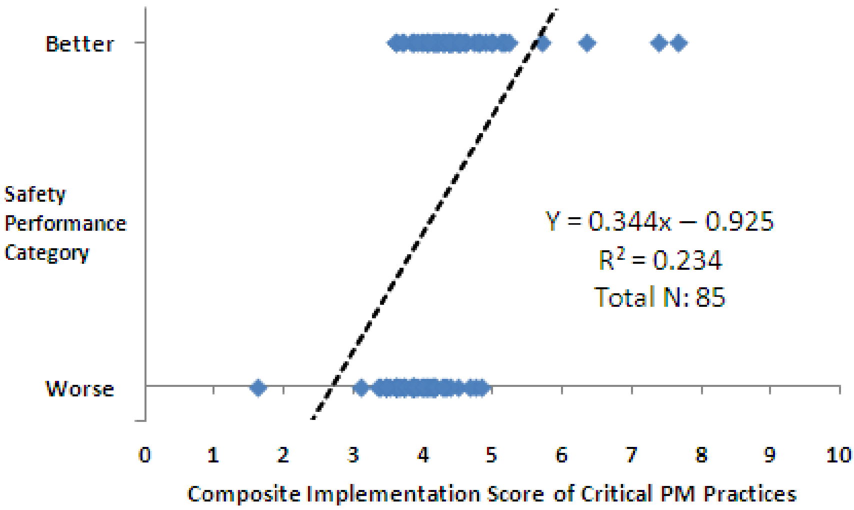
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	35	22	61.4
		Better	18	44	71.0
	Overall Percentage				66.4

Figure 4.12: Logit Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Safety Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on safety performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.13 and 4.14 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.13 shows that the composite implementation score was a significant predictor of safety performance (B=0.344, P-value=0.000). The fitted regression equation (Y = 0.344X − 0.925) also indicated a good model fit (F=35.451, P-value =0.000) and correctly classified 77.3% of 85 owner projects for the safety performance category. The equation implies that that owner projects could achieve better safety performance (Y>0.5) when their composite implementation score was equal or more than 4.15.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.344	.058	.482	5.954	.000
(Constant)	-.925	.246		-3.757	.000

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.906	1	6.906	35.451	0.000
Residual	22.792	117	.195		
Total	29.697	118			

R	R Square	Adjusted R Square
0.482	.233	.226

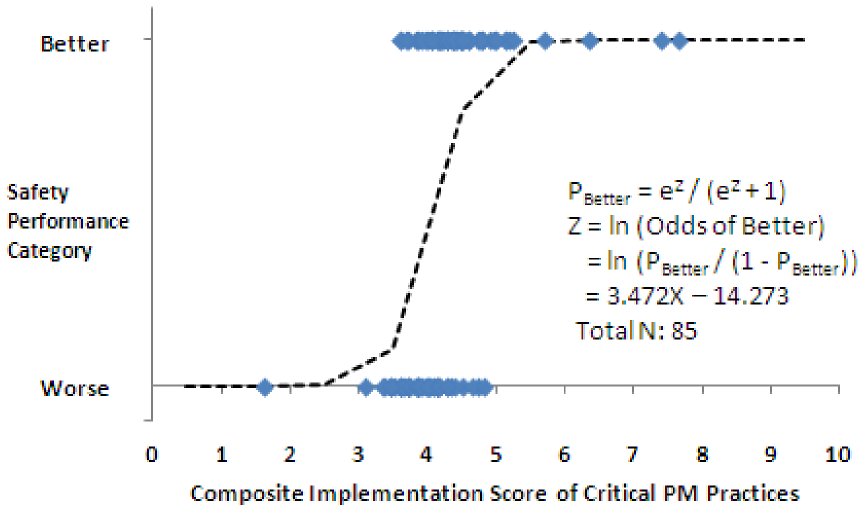
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	46	11	80.7
		Better	16	46	74.2
	Overall Percentage				77.3

Figure 4.13: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Safety Performance

The logit regression analysis results provided in Figure 4.14 also indicates that the composite implementation score was a highly significant predictor of safety performance (B=3.472, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 76.5% of 85 owner projects were correctly classified for the safety performance category. The fitted regression equation ($P_{Better} = e^{(3.472X-14.273)}/(e^{(3.472X-14.273)}+1)$ implies that the odds of better safety performance were increased by a multiplicative factor of 32.194 (=$e^{(3.472)}$) for every one point increase in the composite implementation score. It also indicates that owner projects could achieve better safety performance (Y>0.5) when the composite implementation score of the critical project management attributes were 4.11 or above.

Using OLS regression and logit regression, safety performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with safety performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that safety performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	3.472	.696	24.902	1	.000	32.194
(Constant)	-14.273	2.863	24.845	1	.000	.000

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	3.939	8	.863

Cox & Snell R Square	Nagelkerke R Square
.323	.430

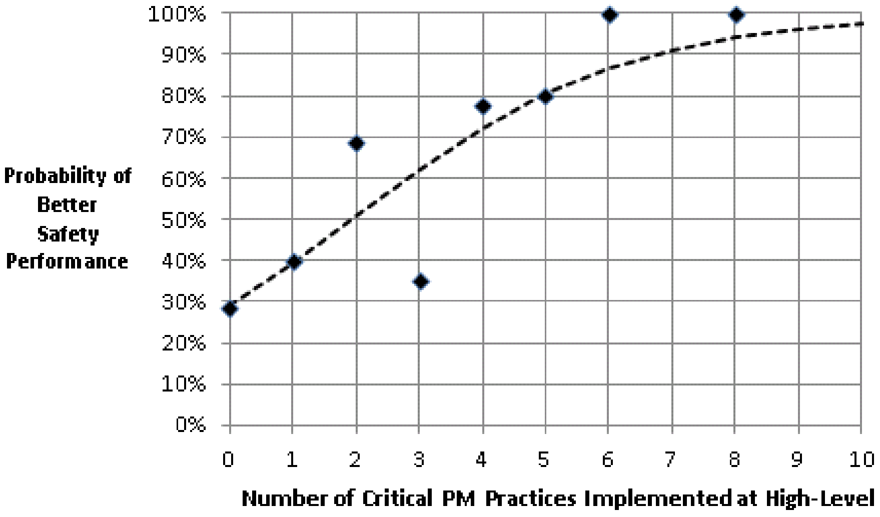
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	43	14	75.4
		Better	14	48	77.4
	Overall Percentage				76.5

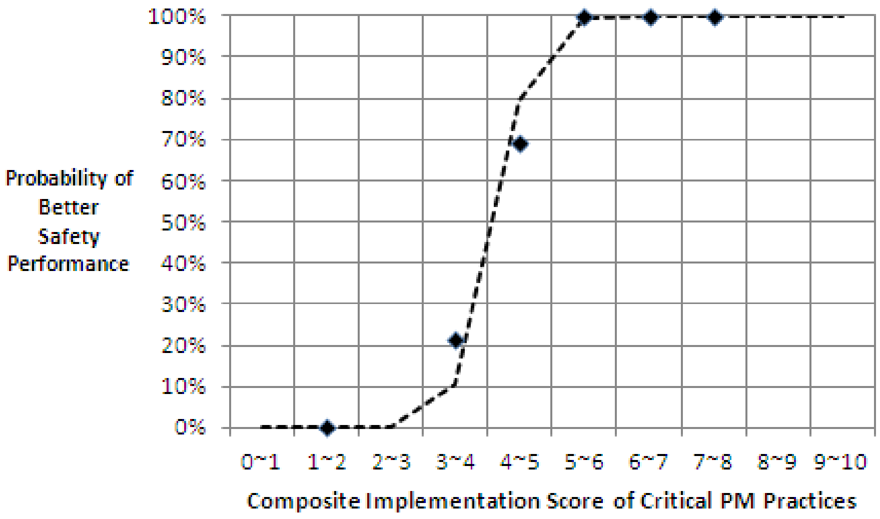
Figure 4.14: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Cost Growth Performance

Figure 4.15 represents changes in the probability of better safety performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better safety performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better safety performance. It can be suggested to implement four or more of the critical project management attributes at high-level and make the composite implementation score over five because projects showed a higher probability of better cost growth performance in such implementation.

To sum up, this chapter identified 10 critical project management attributes significantly related to safety performance when they were implemented with more than a certain level of effort (Table 4.12 and Table 4.13). The regression analyses arranged the 10 critical project management attributes into their order of relative importance (Table 4.14). The combined effects of the 10 project management attributes on safety performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.11 ~ Figure 4.15).



Number of Projects	Better	8	10	11	6	14	8	4	0	1	0	0
	Worse	20	15	5	11	4	2	0	0	0	0	0
	Total	28	25	16	17	18	10	4	0	1	0	0



Number of Projects	Better	0	0	0	10	43	6	1	2	0	0
	Worse	0	1	0	19	37	0	0	0	0	0
	Total	0	1	0	29	80	6	1	2	0	0

Figure 4.15: Probability of Better Safety Performance by Two Indicators

4.1.4 QUALITY PERFORMANCE

Quality performance was evaluated by a survey question asking the level of satisfaction of quality goals. The question used a seven point Likert-scale in which one means "not at all successful" and seven means "extremely successful". As described in Section 3.5.3, the level of satisfaction of quality goals was categorized into two performance categories. Projects whose level of satisfaction of quality goals was seven were categorized into the better performance category, while projects whose level of satisfaction of quality goals was 6 or below were categorized into the worse performance category (Table 4.13).

Table 4.13: Quality Performance Category

	Better Performance Category	Worse Performance Category
Quality Performance	Extremely Successful	Other

Identification of Minimum Implementation Levels for Project Management Attributes

For better quality performance, Table 4.14 shows the minimum implementation levels for 19 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better quality performance than projects implemented below the minimum level. By using the chi-square test and the Fisher's exact test, whether there is a statistically significant difference in the probabilities of better quality performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better quality performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.14: Minimum Implementation Level for Project Management Attributes for Better Quality Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Quality Performance
1	PDRI	7.9	*
2	FEP	9.1	*
3	Alignment	8.6	*
4	Partnering	7.3	
5	Team Building	9.3	
6	Change Management	6.5	*
7	PDCS	9.1	
8	Constructability	2.1	*
9	Project Risk Analysis	8.8	
10	Planning for Startup	9.0	*
11	Zero Accident Technique	7.7	
12	Timely Engineering Deliverables	8.6	
13	Accurate Engineering Deliverables	5.8	
14	Percent Design Completion at AFE	9.6	
15	Percent Design Completion prior to construction	3.2	*
16	Alliance	8.6	*
17	Budget Accuracy	8.1	*
18	Fast Track (Yes or No)	No	
19	Modularization	2.1	*

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to quality performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for quality performance. As shown in Table 4.15, 12 critical project management attributes for quality performance were identified, including PDRI, FEP, alignment, change management, PDCS, constructability, project risk assessment, planning for startup, percent design completion prior to construction, budget accuracy, and modularization.

Table 4.15: Critical Project Management Attributes for Quality Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI	*	*	*	*
2	FEP	*	*	*	*
3	Alignment	*	*	*	*
4	Partnering				
5	Team Building				
6	Change Management	*	*	*	*
7	PDCS	*	*	*	*
8	Constructability	*	*	*	*
9	Project Risk Assessment	*	*	*	*
10	Planning for Startup	*	*	*	*
11	Zero Accident Technique				
12	Timely Engineering Deliverables				
13	Accurate Engineering Deliverables				
14	Percent Design Completion at AFE				
15	Percent Design Completion prior to Construction	*	*	*	*
16	Alliance	*	*	*	*
17	Budget Accuracy	*	*	*	*
18	Fast-track				
19	Modularization	*	*	*	*

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the 12 critical project management attributes for better quality performance, as discussed in Section 3.5.7. For the 12 critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better quality performance. The ranks of the three methods were averaged to generate an overall relative importance of the 12 critical project management attributes, as shown in Table 4.16.

Table 4.16: Relative Importance of Critical Project Management Attributes for Better Quality Performance

	Project management Attribute (High- or Low-Level Implementation Group)	Linear		Logit		Probit		Overall	
		Coeff.	Rank	Coeff.	Rank	Coeff.	Rank	Rank Average	Rank
1	Alignment (High: >=8.6, Low: <8.6)	0.523	1	4.873	1	2.556	1	1.00	1
2	Constructability (High: >=2.1 Low: <2.1)	0.296	2	2.461	3	1.150	3	2.67	2
3	FEP (High: >=9.1, Low: <9.1)	0.199	6	2.496	2	1.289	2	3.33	3
4	Project Risk Assessment (High: >=8.8, Low: <8.8)	0.275	3	1.508	4	0.956	4	3.67	4
5	PDRI (High: >=7.9, Low: <7.9)	0.199	5	1.310	6	0.809	5	5.33	5
6	Modularization (High: >=2.1, Low: <2.1)	0.227	4	1.429	5	0.669	7	5.33	5
7	Alliance (High: >=8.6, Low: <8.6)	0.190	7	1.307	7	0.760	6	6.67	7
8	Change Management (High: >=6.5, Low: <6.5)	0.138	8	1.028	8	0.426	8	8.00	8
9	Percent Design Completion prior to Construction (High: >=3.2, Low: <3.2)	0.056	9	0.213	9	0.185	9	9.00	9
10	Budget Accuracy (High: >=8.1, Low: <8.1)	0.051	10	0.120	10	0.177	10	10.00	10
11	Planning for Startup (High: >=9.0, Low: <9.0)	-0.051	11	-0.978	11	-0.240	11	11.0	11
12	Project Delivery Contract Strategy (High: >=9.1, Low: <9.1)	-0.158	12	-1.589	12	-0.993	12	12.0	12

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the alignment attribute ranked first, which indicates that the implementation of this attribute with a score of 8.6 or above was the most important project management attribute for better quality performance. However, it should be noted that the alignment attribute might not be the most important project management attribute when implemented with less than 8.6.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better quality performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better quality performance. Nonetheless, since all of the 10 critical project management attributes were significantly related to quality performance, the implementation of them all would be the best way to expect higher probability of better quality performance.

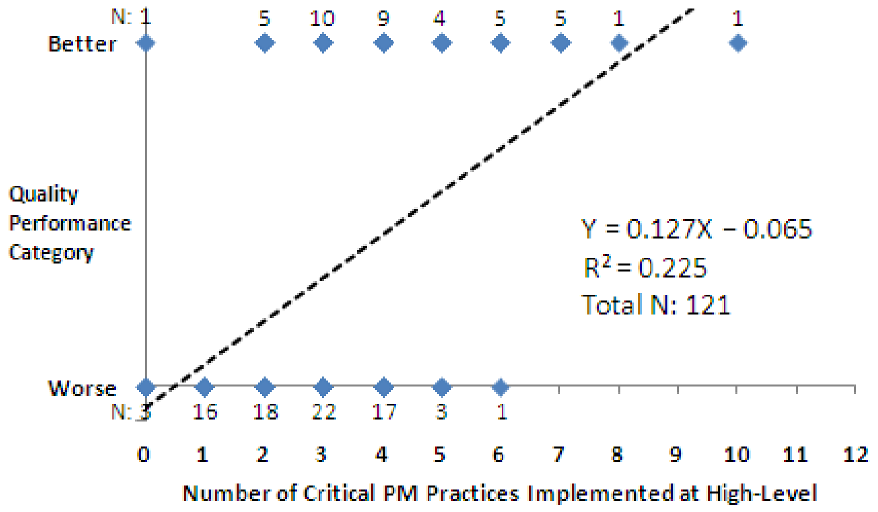
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on quality performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the 12 critical project management attributes for quality performance were divided into low-level or high-level as shown in Table 4.16, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and quality performance was examined. Figure 4.16 and Figure 4.17 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.16 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of quality performance (B=0.127, P-value=0.000). The fitted regression equation ($Y = 0.127X - 0.065$) also indicated a good model fit (F=34.594, P-value=0.000) and correctly classified 76.0% of 121 owner projects for the quality performance category. The equation implies that owner projects could achieve better quality performance ($Y>0.5$) when they executed five or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.127	.022	.475	5.882	.000
(Constant)	-.065	.079		-.829	.409

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.105	1	6.105	34.594	0.000
Residual	21.002	119	.176		
Total	27.107	120			

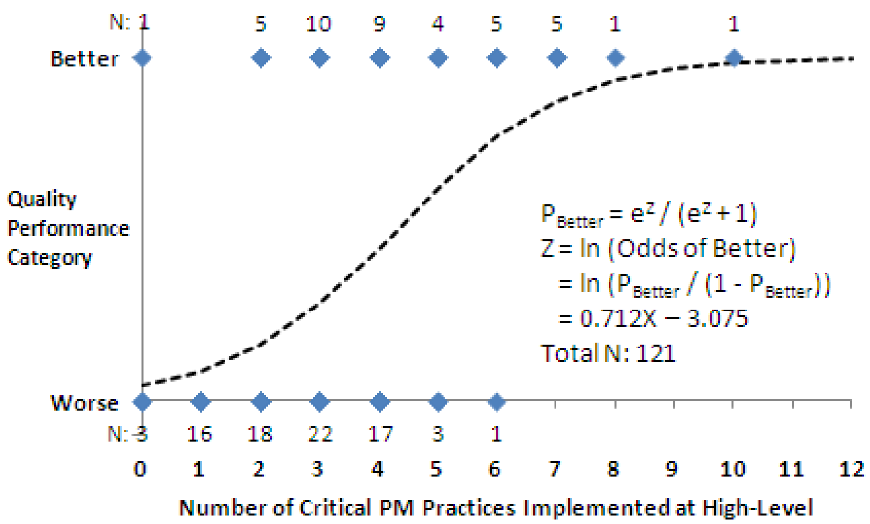
R	R Square	Adjusted R Square
0.475	.225	.219

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	76	4	95.0
		Better	25	16	39.0
	Overall Percentage				76.0

Figure 4.16: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Quality Performance

The logit regression analysis results provided in Figure 4.17 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of quality performance (B=0.712, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 76.0% of 121 owner projects were correctly classified for the quality performance category. The fitted logit regression equation ($P_{Better} = e^{(0.712X-3.075)} / (e^{(0.712X-3.075)}+1)$ implies that the odds of better quality performance were increased by a multiplicative factor of 2.038 ($=e^{(0.712)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that owner projects could achieve better quality performance (Y>0.5) when they executed five or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.712	.159	19.965	1.000	.000	2.038
(Constant)	-3.075	.593	26.901	1.000	.000	.046

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	2.727	4	.605

Cox & Snell R Square	Nagelkerke R Square
.218	.302

Classification Table

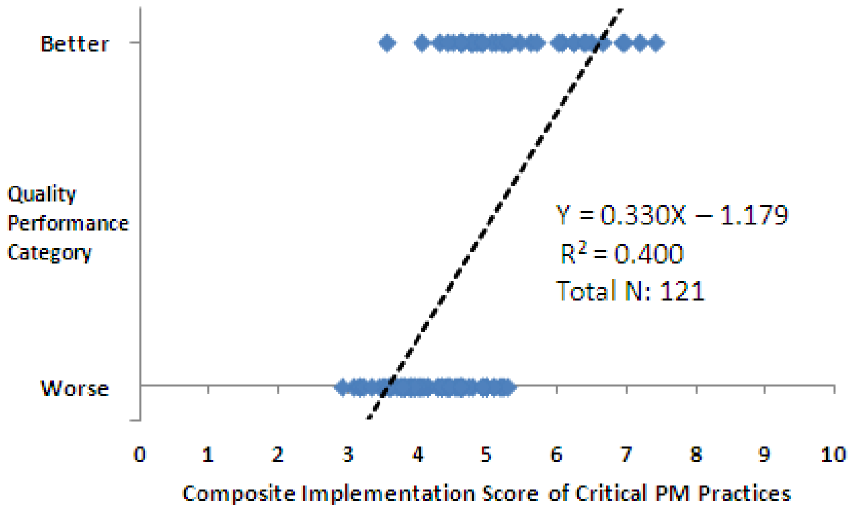
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	76	4	95.0
		Better	25	16	39.0
	Overall Percentage				76.0

Figure 4.17: Logit Regression Analysis Results for Relationship between Number of Critical project management Attributes Implemented at High-Level and Quality Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on quality performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.18 and 4.19 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.18 shows that the composite implementation score was a significant predictor of quality performance (B=0.330, P-value=0.000). The fitted regression equation ($Y = 0.330X - 1.179$) also indicated a good model fit (F=79.474, P-value =0.000) and correctly classified 81.0% of 121 owner projects for the quality performance category. The equation implies that that owner projects could achieve better quality performance ($Y>0.5$) when their composite implementation score was equal or more than 5.09.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.330	.037	.633	8.915	.000
(Constant)	-1.179	.174		-6.794	.000

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	10.854	1	10.854	79.474	0.000
Residual	16.253	119	.137		
Total	27.107	120			

R	R Square	Adjusted R Square
0.633	.400	.395

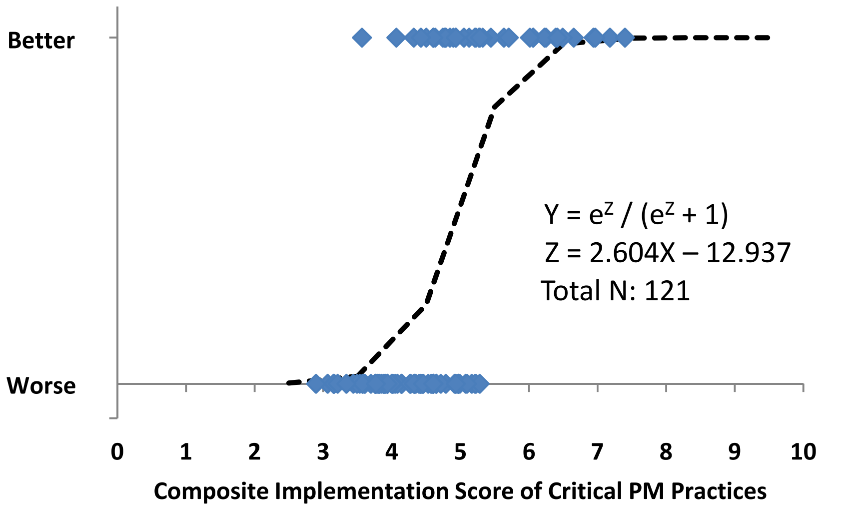
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	75	5	93.8
		Better	18	23	56.1
	Overall Percentage				81.0

Figure 4.18: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Quality Performance

The logit regression analysis results provided in Figure 4.19 also indicates that the composite implementation score was a highly significant predictor of quality performance (B=2.604, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 80.2% of 121 owner projects were correctly classified for the quality performance category. The fitted regression equation ($P_{Better} = e^{(2.604X-12.937)} / (e^{(2.604X-12.937)}+1)$) implies that the odds of better quality performance were increased by a multiplicative factor of 13.523 ($=e^{(2.604)}$) for every one point increase in the composite implementation score. It also indicates that owner projects could achieve better quality performance (Y>0.5) when the composite implementation score of the critical project management attributes were 4.97 or above.

Using OLS regression and logit regression, quality performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with quality performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that quality performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	2.604	.523	24.835	1	.000	13.523
(Constant)	-12.937	2.493	26.938	1	.000	.000

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	13.056	8	.110

Cox & Snell R Square	Nagelkerke R Square
.390	.540

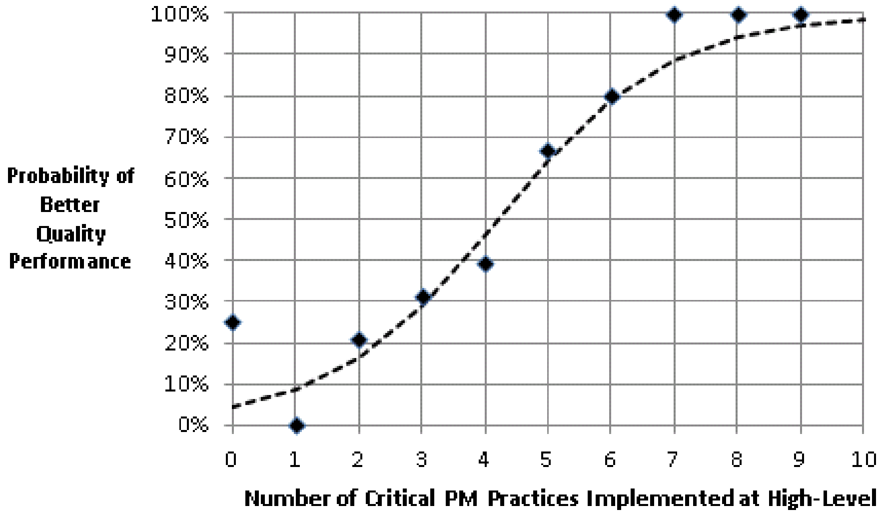
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	73	7	91.3
		Better	17	24	58.5
	Overall Percentage				80.2

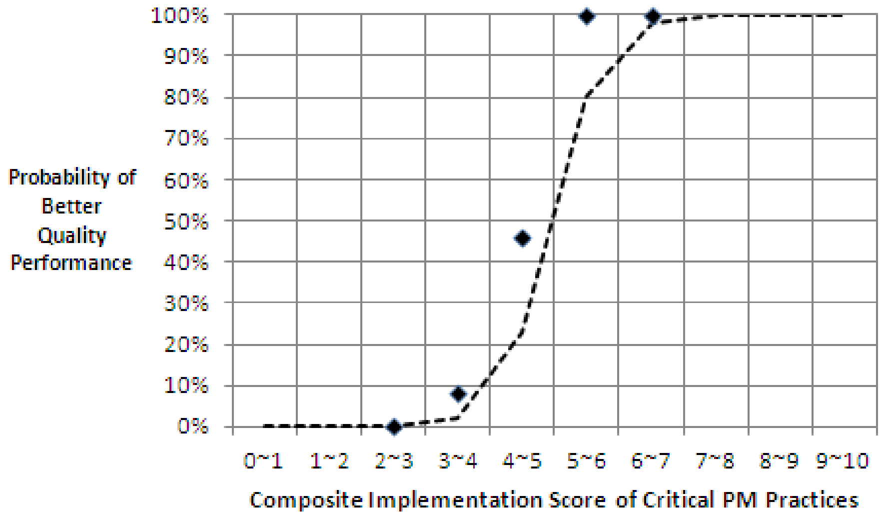
Figure 4.19: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Cost Growth Performance

Figure 4.20 represents changes in the probability of better quality performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better quality performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better quality performance. It can be suggested to implement six or more of the critical project management attributes at high-level and make the composite implementation score over five because projects showed a higher probability of better cost growth performance in such implementation.

To sum up, this chapter identified 12 critical project management attributes significantly related to quality performance when they were implemented with more than a certain level of effort (Table 4.14 and Table 4.15). The regression analyses arranged the 12 critical project management attributes into their order of relative importance (Table 4.16). The combined effects of the 10 project management attributes on quality performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.16 ~ Figure 4.20).



Number of Projects	Better	1	0	5	10	11	4	4	4	1	1	0
	Worse	3	16	19	22	17	2	1	0	0	0	0
	Total	4	16	24	32	28	6	5	4	1	1	0



Number of Projects	Better	0	0	0	4	22	10	5	0	0	0
	Worse	0	0	9	45	26	0	0	0	0	0
	Total	0	0	9	49	48	10	5	0	0	0

Figure 4.20: Probability of Better Quality Performance by Two Indicators

4.1.5 BUSINESS PERFORMANCE

Business performance was evaluated by a survey question asking the level of satisfaction of business goals. The question used a seven point Likert-scale in which one means “not at all successful” and seven means “extremely successful”. As described in Section 3.5.3, the level of satisfaction of business goals was categorized into two performance categories. Projects whose level of satisfaction of business goals was seven were categorized into the better performance category, while projects whose level of satisfaction of business goals was six or below were categorized into the worse performance category (Table 4.17).

Table 4.17: Business Performance Category

	Better Performance Category	Worse Performance Category
Business Performance	Extremely Successful	Other

Identification of Minimum Implementation Levels for Project Management Attributes

For better business performance, Table 4.18 shows the minimum implementation levels for 19 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better business performance than projects implemented below the minimum level. By using the chi-square test and the Fisher’s exact test, whether there is a statistically significant difference in the probabilities of better business performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better business performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.18: Minimum Implementation Level for Project Management Attributes for Better Business Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Business Performance
1	PDRI	8.3	*
2	FEP	8.1	*
3	Alignment	7.6	*
4	Partnering	7.3	*
5	Team Building	9.3	
6	Change Management	6.1	*
7	PDCS	8.9	
8	Constructability	7.9	
9	Project Risk Analysis	1.3	*
10	Planning for Startup	8.3	*
11	Zero Accident Technique	8.4	
12	Timely Engineering Deliverables	4.3	*
13	Accurate Engineering Deliverables	7.2	
14	Percent Design Completion at AFE	5.1	*
15	Percent Design Completion prior to construction	3.2	*
16	Alliance	8.6	*
17	Budget Accuracy	8.1	*
18	Fast Track (Yes or No)	Yes	
19	Modularization	2.1	

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to business performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for business performance. As shown in Table 4.19, 14 critical project management attributes for business performance were identified, including PDRI, FEP, alignment, change management, project risk assessment, planning for startup, zero accident technique, timely engineering deliverables, timely engineering deliverables, percent design completion at AFE, percent design completion prior to construction, alliance, and budget accuracy.

Table 4.19: Critical Project Management Attributes for Business Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI	*	*	*	*
2	FEP	*	*	*	*
3	Alignment	*	*	*	*
4	Partnering	*	*	*	*
5	Team Building				
6	Change Management	*	*	*	*
7	PDCS				
8	Constructability				
9	Project Risk Assessment	*	*	*	*
10	Planning for Startup	*	*	*	*
11	Zero Accident Technique	*	*	*	*
12	Timely Engineering Deliverables	*	*	*	*
13	Accurate Engineering Deliverables	*	*	*	*
14	Percent Design Completion at AFE	*	*	*	*
15	Percent Design Completion prior to Construction	*	*	*	*
16	Alliance	*	*	*	*
17	Budget Accuracy	*	*	*	*
18	Fast-track				
19	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the 14 critical project management attributes for better business performance, as discussed in Section 3.5.7. For the 14 critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better business performance. The ranks of the three methods were averaged to generate an overall relative importance of the 14 critical project management attributes, as shown in Table 4.20.

Table 4.20: Relative Importance of Critical Project Management Attributes for Better Business Performance

	Project management Attribute (High- or Low-Level Implementation Group)	Linear		Logit		Probit		Overall	
		Coef	Rank	Coef	Rank	Coef	Rank	Rank Average	Rank
1	Alignment (High: >=7.6, Low: <7.6)	0.244	1	1.557	2	0.930	2	1.67	1
2	Percent Design Completion prior at AFE (High: >=5.1, Low: <5.1	0.167	3	1.478	3	0.857	3	3.00	2
3	PDRI (High: >=8.3, Low: <8.3)	0.184	2	1.179	6	0.498	4	4.00	3
4	Partnering (High: >=7.3, Low: <7.3)	0.056	11	1.700	1	0.942	1	4.33	4
5	Project Risk Assessment (High: >=1.30, Low: <1.3)	0.146	6	1.460	4	0.747	5	5.00	5
5	Timely Engineering Deliverables (High: >=4.3, Low: <4.3)	0.166	4	1.195	5	0.648	6	5.00	5
7	Zero Accident Technique (High: >=8.4, Low: <8.4)	0.150	5	0.971	8	0.569	7	6.67	7
8	FEP (High: >=8.1, Low: <8.1)	0.116	8	1.007	7	0.498	8	7.67	8
9	Change Management (High: >=6.1 Low: <6.1)	0.106	9	0.721	10	0.446	9	9.33	9
9	Budget Accuracy (High: >=8.1, Low: <8.1)	0.140	7	0.708	11	0.390	10	9.33	9
11	Planning for Startup (High: >=8.3, Low: <8.3)	0.095	10	0.753	9	0.345	11	10.00	11
12	Alliance (High: >=8.6, Low: <8.6)	0.054	12	0.336	12	0.104	12	12.00	12
13	Accurate Engineering (High: >=7.2, Low: <7.2)	0.054	14	-0.033	13	-0.012	13	13.33	13
14	Percent Design Completion prior to Construction (High: >=3.2, Low: <3.2	0.014	13	-0.085	14	-0.074	14	13.67	14

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the alignment ranked first, which indicates that the implementation of this attribute with a score of 7.6 or above was the most important project management attribute for better business performance. However, it should be noted that the alignment attribute might not be the most important project management attribute when implemented with less than 7.6.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better business performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better business performance. Nonetheless, since all of the 14 critical project management attributes were significantly related to business performance, the implementation of them all would be the best way to expect higher probability of better business performance.

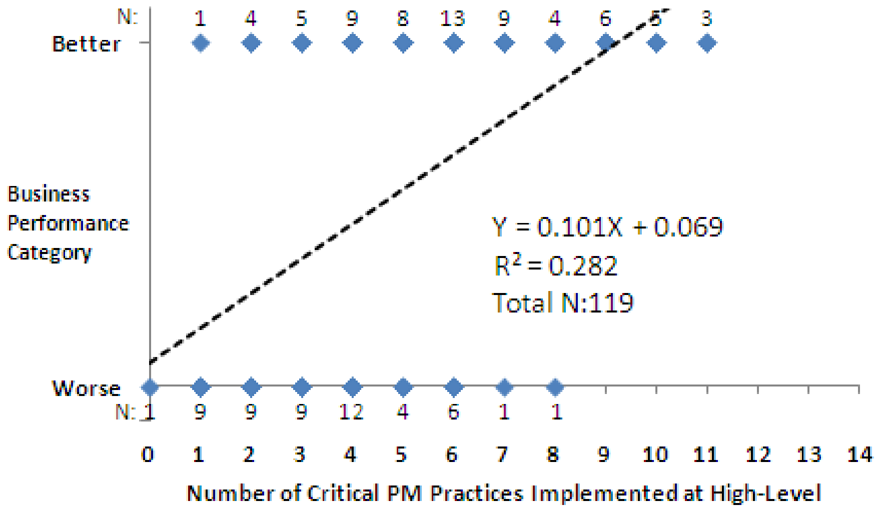
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on business performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the 14 critical project management attributes for business performance were divided into low-level or high-level as shown in Table 4.20, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and business performance was examined. Figure 4.21 and Figure 4.22 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.21 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of business performance (B=0.101, P-value=0.000). The fitted regression equation ($Y = 0.101X + 0.069$) also indicated a good model fit (F=45.858, P-value =0.000) and correctly classified 73.9% of 119 owner projects for the business performance category. The equation implies that owner projects could achieve better business performance ($Y>0.5$) when they executed four or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.101	.015	.531	6.772	.000
(Constant)	.069	.083		.835	.405

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	8.244	1	8.244	45.858	0.000
Residual	21.033	117	.180		
Total	29.277	118			

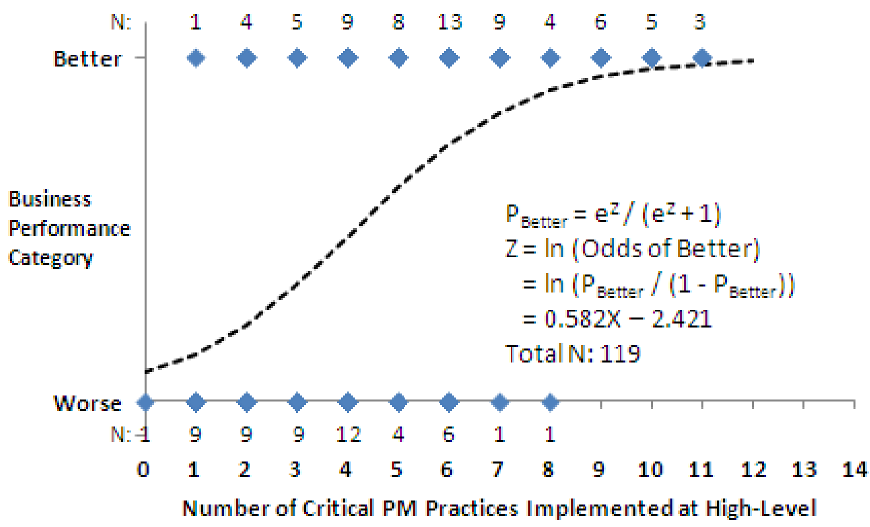
R	R Square	Adjusted R Square
0.531	.282	.275

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	40	12	76.9
		Better	19	48	71.6
	Overall Percentage				73.9

Figure 4.21: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Business Performance

The logit regression analysis results provided in Figure 4.22 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of business performance (B=0.582, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 73.9% of 119 owner projects were correctly classified for the business performance category. The fitted logit regression equation ($P_{Better} = e^{(0.582X-2.421)} / (e^{(0.582X-2.421)}+1)$) implies that the odds of better business performance were increased by a multiplicative factor of 1.789 ($=e^{(0.582)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that owner projects could achieve better business performance (Y>0.5) when they executed five or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.582	.116	25.071	1.000	.000	1.789
(Constant)	-2.421	.552	19.248	1.000	.000	.089

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	1.958	7	.962

Cox & Snell R Square	Nagelkerke R Square
.284	.380

Classification Table

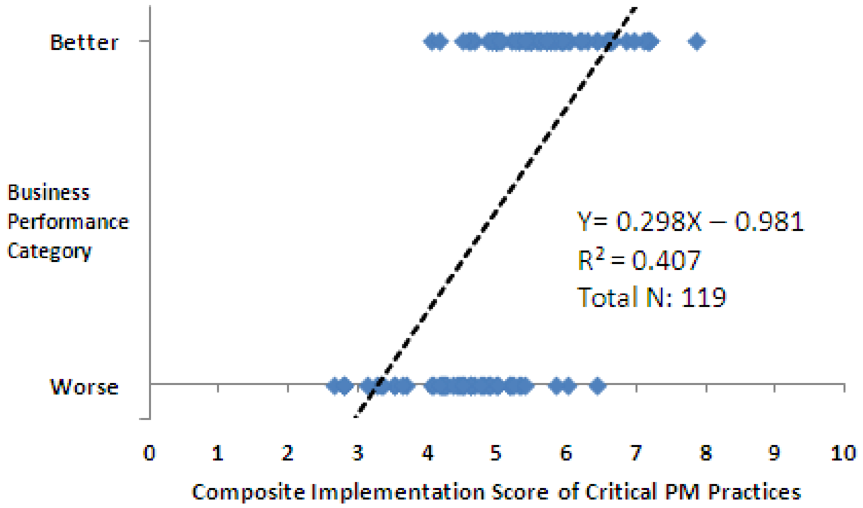
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	40	12	76.9
		Better	19	48	71.6
	Overall Percentage				73.9

Figure 4.22: Logit Regression Analysis Results for Relationship between Number of Critical project management Attributes Implemented at High-Level and Business Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on business performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.23 and 4.24 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.23 shows that the composite implementation score was a significant predictor of business performance (B=0.298, P-value=0.000). The fitted regression equation ($Y = 0.298X - 0.981$) also indicated a good model fit (F=80.147, P-value =0.000) and correctly classified 81.5% of 119 owner projects for the business performance category. The equation implies that that owner projects could achieve better business performance ($Y>0.5$) when their composite implementation score was equal or more than 4.97.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.298	.033	.638	8.952	.000
(Constant)	-.981	.176		-5.571	.000

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	11.902	1	11.902	80.147	0.000
Residual	17.375	117	.149		
Total	29.277	118			

R	R Square	Adjusted R Square
0.638	.407	.401

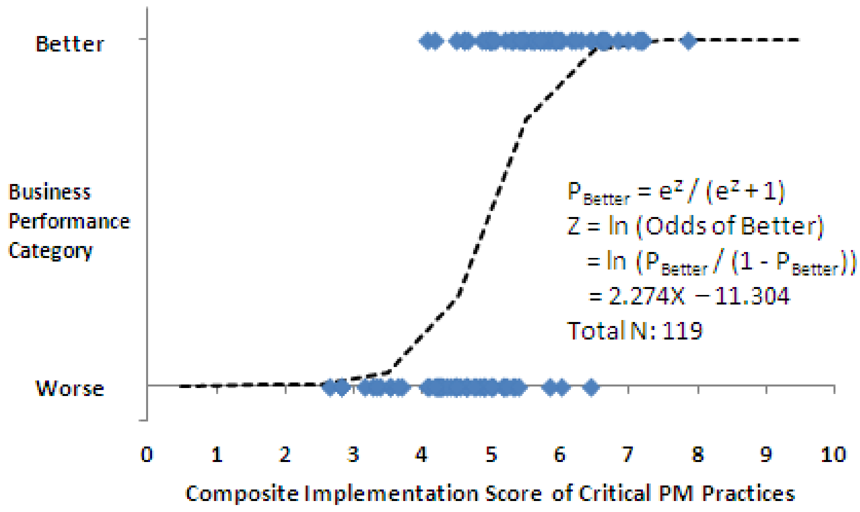
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	39	13	75.0
		Better	9	58	86.6
	Overall Percentage				81.5

Figure 4.23: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Business Performance

The logit regression analysis results provided in Figure 4.19 also indicates that the composite implementation score was a highly significant predictor of business performance (B=2.274, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 81.5% of 121 owner projects were correctly classified for the business performance category. The fitted regression equation ($P_{Better} = e^{(2.274X-11.304)} / (e^{(2.274X-11.304)}+1)$ implies that the odds of better business performance were increased by a multiplicative factor of 9.719 ($=e^{(2.274)}$) for every one point increase in the composite implementation score. It also indicates that owner projects could achieve better business performance (Y>0.5) when the composite implementation score of the critical project management attributes were 4.97 or above.

Using OLS regression and logit regression, business performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with business performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that business performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	2.274	.432	27.751	1	.000	9.719
(Constant)	-11.304	2.185	26.761	1	.000	.000

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	5.930	8	.655

Cox & Snell R Square	Nagelkerke R Square
.414	.555

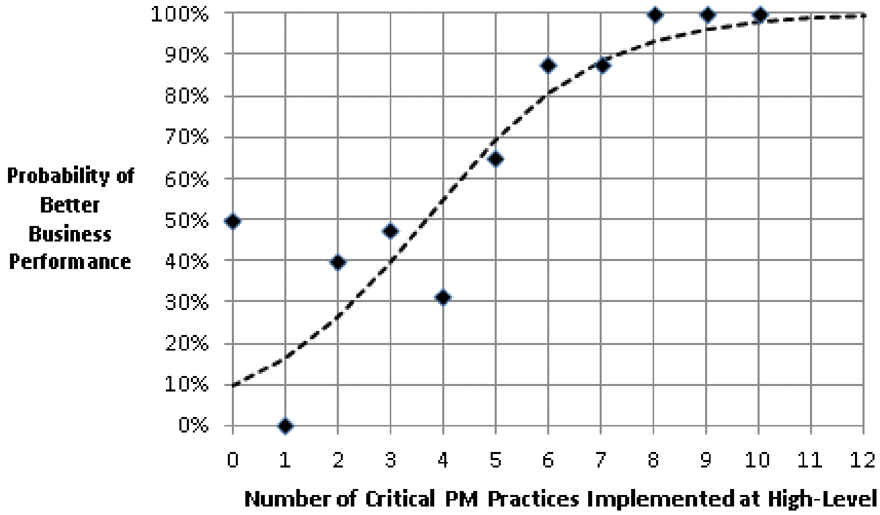
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	39	13	75.0
		Better	9	58	86.6
	Overall Percentage				81.5

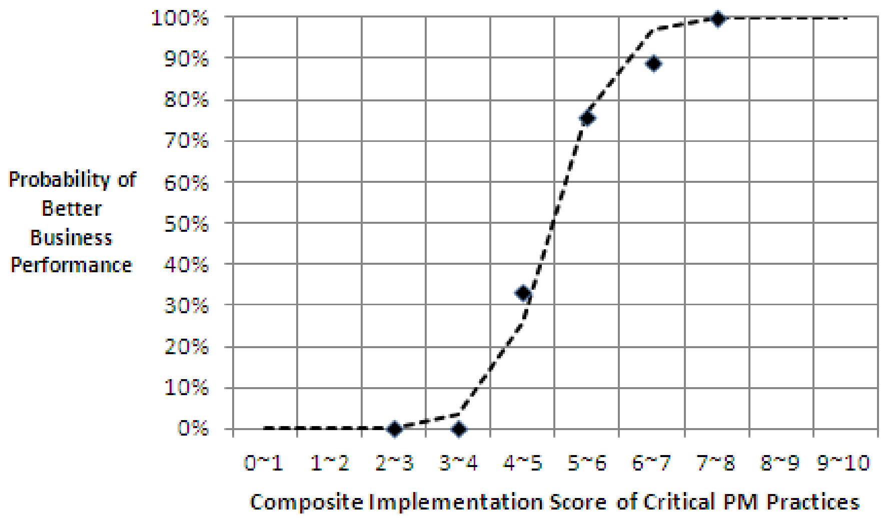
Figure 4.24: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Cost Growth Performance

Figure 4.25 represents changes in the probability of better business performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better business performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better business performance. It can be suggested to implement six or more of the critical project management attributes at high-level and make the composite implementation score over six because projects showed a higher probability of better business performance in such implementation.

To sum up, this chapter identified 14 critical project management attributes significantly related to business performance when they were implemented with more than a certain level of effort (Table 4.18 and Table 4.19). The regression analyses arranged the 14 critical project management attributes into their order of relative importance (Table 4.20). The combined effects of the 14 project management attributes on business performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.21 ~ Figure 4.25).



Number of Projects														
	Better	1	0	6	10	5	11	14	7	5	3	5	0	0
	Worse	1	11	9	11	11	6	2	1	0	0	0	0	0
	Total	2	11	15	21	16	17	16	8	5	3	5	0	0



Number of Projects											
	Better	0	0	0	2	12	23	22	7	1	0
	Worse	0	0	8	7	27	9	1	0	0	0
	Total	0	0	8	9	39	32	23	7	1	0

Figure 4.25: Probability of Better Business Performance by Two Indicators

4.1.6 DISCUSSION

This section discusses the implications of the analysis results described in the previous five sections. Each of the five sections identified critical project management attributes specifically for cost, schedule, safety, quality, or business performance and suggested the implementation levels for them. Table 4.21 summarizes the identified critical project management attributes and their minimum implementation levels for each of the five performance outcomes. Each column suggests a strategic guideline that can be useful in implementing project management attributes for a single performance outcome. For example, if a project only focuses on cost performance, then the analysis results under cost performance can be a reference for the selection and implementation of appropriate project management attributes.

When the goal of a project is to improve on multiple performance outcomes, it is necessary to consider the analysis results synthetically. Suppose that a project wants to achieve better performance in both cost and schedule. Since the critical project management attributes and their minimum implementation levels for the two performance outcomes are different, it is necessary to combine their analysis results to provide an implementation guideline that can be simultaneously useful for the two performance outcomes.

Table 4.21: Critical Project Management Attributes and Minimum Implementation Level

Project Management Attribute		Cost Performance		Schedule Performance		Safety Performance		Quality Performance		Business Performance	
		Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.
1	PDRI	8.7	*	6.7		8.0		7.9	*	8.3	*
2	FEP	7.7	*	7.5	*	9.1	*	9.1	*	8.1	*
3	Alignment	5.7	*	6.0	*	7.2	*	8.6	*	7.6	*
4	Partnering	6.3	*	6.0	*	7.0	*	7.3		7.3	*
5	Team Building	9.3		6.7	*	9.3		9.3		9.3	
6	Change Management	8.1	*	6.2	*	8.6		6.5	*	6.1	*
7	PDCS	8.3	*	6.2	*	8.8	*	9.1	*	8.9	
8	Constructability	8.0		7.8		7.8	*	2.1	*	7.9	
9	Project Risk Analysis	8.6		4.4	*	7.4	*	8.8	*	1.3	*
10	Planning for Startup	5.6	*	7.0	*	6.9	*	9.0	*	8.3	*
11	Zero Accident Technique	6.7		5.4		6.4	*	7.7		8.4	*
12	Timely Engineering	4.3	*	7.2	*	8.6	*	8.6		4.3	*
13	Accurate Engineering	7.2	*	7.2	*	4.3	*	5.8		7.2	*
14	Percent Design Completion at AFE	4.1	*	0.8		4.1		9.6		5.1	*
15	Percent Design Completion prior to construction	3.2	*	3.2	*	2.6		3.2	*	3.2	*
16	Alliance	7.2	*	5.8	*	8.6		8.6	*	8.6	*
17	Budget Accuracy	6.1		6.1		8.1		8.1	*	8.1	*
18	Fast Track (Yes or No)	Yes		Yes		Yes		No		Yes	
19	Modularization	0.1		3.1		2.1	*	2.1	*	2.1	

Table 4.22 shows an example of how the implementation level for both cost and schedule performance outcomes is recommended. Between the implementation levels for the two performance outcomes, the higher implementation level can be chosen from a conservative point of view. For instance, the implementation level of FEP for cost performance is 7.7, while the implementation level of FEP for schedule performance outcome is 7.5. In this case, 7.7 is the minimum implementation level for combined goal of cost and schedule performance improvement. The last column shows the conservatively minimum implementation levels for each project management attribute.

Table 4.22: Example of Implication of Table 4.21

Project Management Attribute		Cost Performance		Schedule Performance		Cost & Schedule Performance	
		Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.
1	PDRI	8.7	*	6.7		8.7	C
2	FEP	7.7	*	7.5	*	7.7	B
3	Alignment	5.7	*	6.0	*	6.0	B
4	Partnering	6.3	*	6.0	*	6.3	B
5	Team Building	9.3		6.7	*	9.3	S
6	Change Management	8.1	*	6.2	*	8.1	B
7	PDCS	8.3	*	6.2	*	8.3	B
8	Constructability	8.0		7.8		8.0	
9	Project Risk Analysis	8.6		4.4	*	8.6	S
10	Planning for Startup	5.6	*	7.0	*	7.0	B
11	Zero Accident Technique	6.7		5.4		6.7	
12	Timely Engineering Deliverables	4.3	*	7.2	*	7.2	B
13	Accurate Engineering Deliverables	7.2	*	7.2	*	7.2	B
14	Percent Design Completion at AFE	4.1	*	0.8		4.1	C
15	Percent Design Completion prior to Construction	3.2	*	3.2	*	3.2	B
16	Alliance	7.2	*	5.8	*	7.2	B
17	Budget Accuracy	6.1		6.1		6.1	
18	Fast Track (Yes or No)	Yes		Yes		Yes	
19	Modularization	0.1		3.1		3.1	

B: Both, C: Cost, and S: Schedule

To achieve better cost and schedule performance at the same time, the most appropriate strategy might be to implement all of the 14 project management attributes related to either cost or schedule performance outcome. It may be preferable to focus on implementing the 10 project management attributes shown to have a significant relationship with both cost and schedule performance outcomes (FEP, alignment, partnering, change management, PDCS, planning for startup, timely engineering deliverables, accurate engineering deliverables, percent design completion prior to construction, and alliance). However, it is difficult to assert that these 10 project management attributes are more important than the other six attributes solely because of their relationship with both performance outcomes. For example, although the PDRI attribute is a critical project management attribute for cost performance, but not for schedule performance, it is the most critical attribute for good cost performance as shown in Table 4.3. Therefore, it would be best to implement all of the 14 critical project management attributes to the minimum implementation level.

In the same way described in the previous example, the most appropriate project management implementation guideline can be developed for each combination of project performance outcomes. Since projects have different performance goals, a project management implementation guideline tailored to a project's performance goal should be most helpful. Table 4.21 is expected to provide such a project management implementation guideline for owner projects.

4.2 Contractor Projects

4.2.1 Cost Performance

Cost performance was evaluated by using the budget factor metric {Actual Total Project Cost / (Initial Planned Project Cost + Approved Change Cost)}. This metric measures cost performance as a ratio of actual project cost to initial planned project cost with approved change cost. As described in Section 3.5.3, the budget factor metric was preprocessed and categorized into two performance categories. Projects whose budget factor metric was equal to or less than one were categorized into the better performance category, while projects whose budget factor metric was greater than one were categorized into the worse performance category (Table 4.23).

Table 4.23: Budget Factor Performance Category

	Better Performance Category	Worse Performance Category
Budget Factor	< = 1	> 1

Identification of Minimum Implementation Levels for Project Management Attributes

For better budget factor performance, Table 4.24 shows the minimum implementation levels for 16 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better budget factor performance than projects implemented below the minimum level. By using the chi-square test and the Fisher's exact test, whether there is a statistically significant difference in the probabilities of better budget factor performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better budget factor performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.24: Minimum Implementation Level for Project Management Attributes for Better Budget Factor Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Budget Factor Performance
1	PDRI	6.8	*
2	FEP	5.8	
3	Alignment	5.0	
4	Partnering	6.4	
5	Team Building	-	
6	Change Management	7.7	*
7	Constructability	3.8	*
8	Project Risk Analysis	1.1	*
9	Planning for Startup	6.1	*
10	Zero Accident Technique	5.6	
11	Timely Engineering Deliverables	7.6	
12	Accurate Engineering Deliverables	5.8	*
13	Alliance	5.8	
14	Budget Accuracy	6.1	*
15	Fast Track (Yes or No)	Yes	
16	Modularization	1.1	

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to budget factor performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for budget factor performance. As shown in Table 4.25, seven critical project management attributes for budget factor performance were identified, including PDRI, change management, constructability, project risk assessment, planning for startup, accurate engineering deliverables, and budget accuracy.

Table 4.25: Critical Project Management Attributes for Budget Factor Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI	*	*	*	*
2	FEP				
3	Alignment				
4	Partnering				
5	Team Building				
6	Change Management	*	*	*	*
7	Constructability	*	*	*	*
8	Project Risk Assessment	*	*	*	*
9	Planning for Startup	*	*	*	*
10	Zero Accident Technique				
11	Timely Engineering Deliverables				
12	Accurate Engineering Deliverables	*	*	*	*
13	Alliance				
14	Budget Accuracy	*	*	*	*
15	Fast-track				
16	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the seven critical project management attributes for better budget factor performance, as discussed in Section 3.5.7. For the seven critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better budget factor performance. The ranks of the three methods were averaged to generate an overall relative importance of the seven critical project management attributes, as shown in Table 4.26.

Table 4.26: Relative Importance of Critical Project Management Attributes for Better Budget Factor Performance

	Project management Attribute (High- or Low-Level Implementation Group)	Linear		Logit		Probit		Overall	
		Coeff.	Rank	Coeff.	Rank	Coeff.	Rank	Rank Average	Rank
1	Constructability (High: >=3.8, Low: <3.8)	0.342	1	2.442	1	1.353	1	1.00	1
2	Planning for Startup (High: >=6.1, Low: <6.1)	0.300	2	1.726	2	0.958	2	2.00	2
3	PDRI (High: >=6.8, Low: <6.8)	0.288	3	1.586	3	0.890	3	3.00	3
4	Project Risk Assessment (High: >=1.1, Low: <1.1)	0.238	4	1.523	4	0.800	4	4.00	4
5	Budget Accuracy (High: >=6.1, Low: <6.1)	0.204	5	1.386	5	0.786	5	5.00	5
6	Accurate Engineering Deliverables (High: >=5.8, Low: <5.8)	0.111	6	0.835	6	0.512	6	6.00	6
7	Change Management (High: >=7.7, Low: <7.7)	0.100	7	0.804	7	0.406	7	7.00	7

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the constructability attribute ranked first, which indicates that the implementation of this attribute with a score of 3.8 or above was the most important project management attribute for better budget factor performance. However, it should be noted that the constructability attribute might not be the most important project management attribute when implemented with less than 3.8.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better budget factor performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better budget factor performance. Nonetheless, since all of the seven critical project management attributes were significantly related to budget factor performance, the implementation of them all would be the best way to expect higher probability of better budget factor performance.

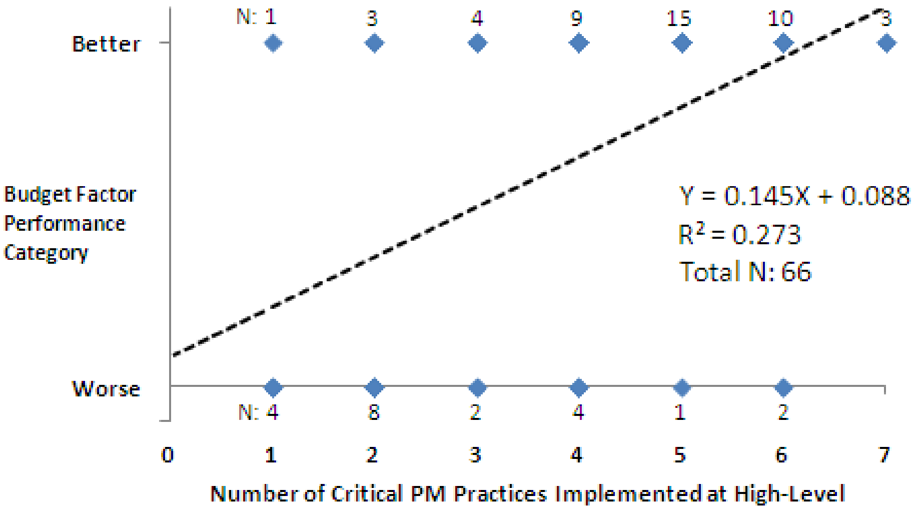
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on budget factor performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the 7 critical project management attributes for budget factor performance were grouped into low-level or high-level as shown in Table 4.26, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and budget factor performance was examined. Figure 4.26 and Figure 4.27 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.26 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of budget factor performance (B=0.145, P-value=0.000). The fitted regression equation (Y = 0.145X + 0.088) also indicated a good model fit (F=23.996, P-value =0.000) and correctly classified 80.3% of 66 contractor projects for the budget factor performance category. The equation implies that contractor projects could achieve better budget factor performance (Y>0.5) when they executed three or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.145	.030	.522	4.899	.000
(Constant)	.088	.131		.674	.503

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.904	1	3.904	23.996	0.000
Residual	10.414	64	.163		
Total	14.318	65			

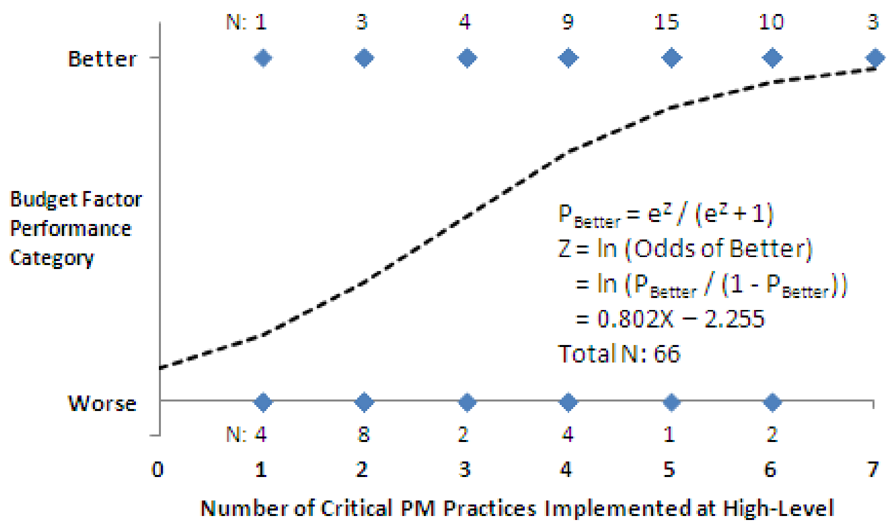
R	R Square	Adjusted R Square
0.522	.273	.261

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	12	9	57.1
		Better	4	41	91.1
	Overall Percentage				80.3

Figure 4.26: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Budget Factor Performance

The logit regression analysis results provided in Figure 4.27 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of budget factor performance (B=0.802, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 80.3% of 66 contractor projects were correctly classified for the budget factor performance category. The fitted logit regression equation ($P_{Better} = e^{(0.802X-2.255)} / (e^{(0.802X-2.255)}+1)$) implies that the odds of better budget factor performance were increased by a multiplicative factor of 2.230 ($=e^{(0.802)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that contractor projects could achieve better budget factor performance (Y>0.5) when they executed three or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.802	.213	14.226	1.000	.000	2.230
(Constant)	-2.255	.812	7.703	1.000	.006	.105

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	2.806	4	.591

Cox & Snell R Square	Nagelkerke R Square
.255	.357

Classification Table

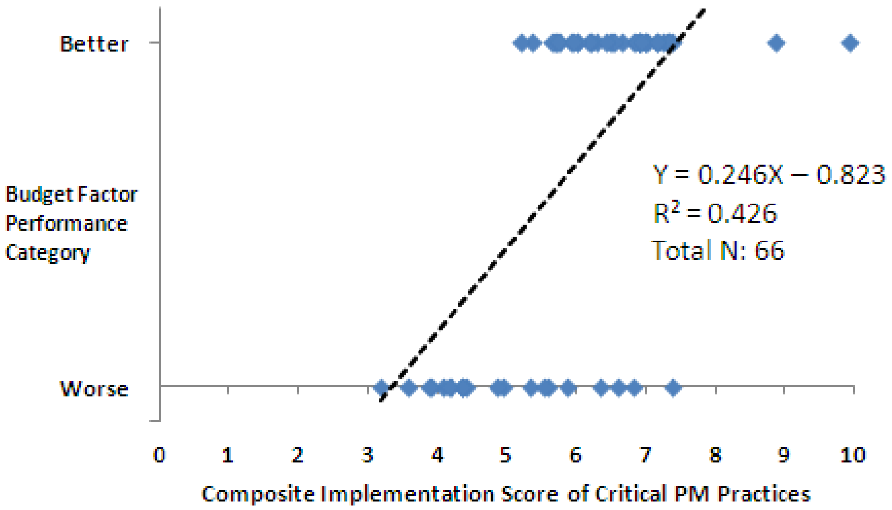
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	12	9	57.1
		Better	4	41	91.1
	Overall Percentage				80.3

Figure 4.27: Logit Regression Analysis Results for Relationship between Number of Critical project management Attributes Implemented at High-Level and Budget Factor Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on budget factor performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.28 and 4.29 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.28 shows that the composite implementation score was a significant predictor of budget factor performance (B=0.246, P-value=0.000). The fitted regression equation ($Y = 0.246X - 0.823$) also indicated a good model fit (F=47.568, P-value =0.000) and correctly classified 86.4% of 66 contractor projects for the budget factor performance category. The equation implies that that contractor projects could achieve better budget factor performance ($Y>0.5$) when their composite implementation score was equal or more than 5.39.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.246	.036	.653	6.897	.000
(Constant)	-.823	.223		-3.697	.000

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.105	1	6.105	47.568	0.000
Residual	8.213	64	.128		
Total	14.318	65			

R	R Square	Adjusted R Square
0.653	.426	.417

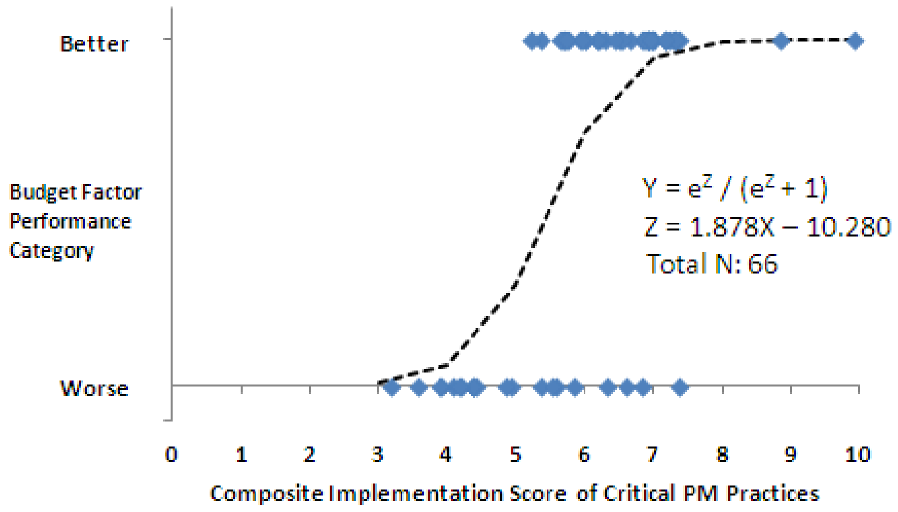
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	14	7	66.7
		Better	2	43	95.6
	Overall Percentage				86.4

Figure 4.28: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Budget Factor Performance

The logit regression analysis results provided in Figure 4.29 also indicates that the composite implementation score was a highly significant predictor of budget factor performance (B=1.878, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 86.4% of 66 contractor projects were correctly classified for the budget factor performance category. The fitted regression equation ($P_{Better} = e^{(1.878X-10.280)} / (e^{(1.878X-10.280)}+1)$) implies that the odds of better budget factor performance were increased by a multiplicative factor of 6.539 ($=e^{(1.878)}$) for every one point increase in the composite implementation score. It also indicates that contractor projects could achieve better budget factor performance (Y>0.5) when the composite implementation score of the critical project management attributes were 5.47 or above.

Using OLS regression and logit regression, budget factor performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with budget factor performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that budget factor performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	1.878	.460	16.669	1	.000	6.539
(Constant)	-10.280	2.705	14.440	1	.000	.000

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	8.817	7	.266

Cox & Snell R Square	Nagelkerke R Square
.413	.578

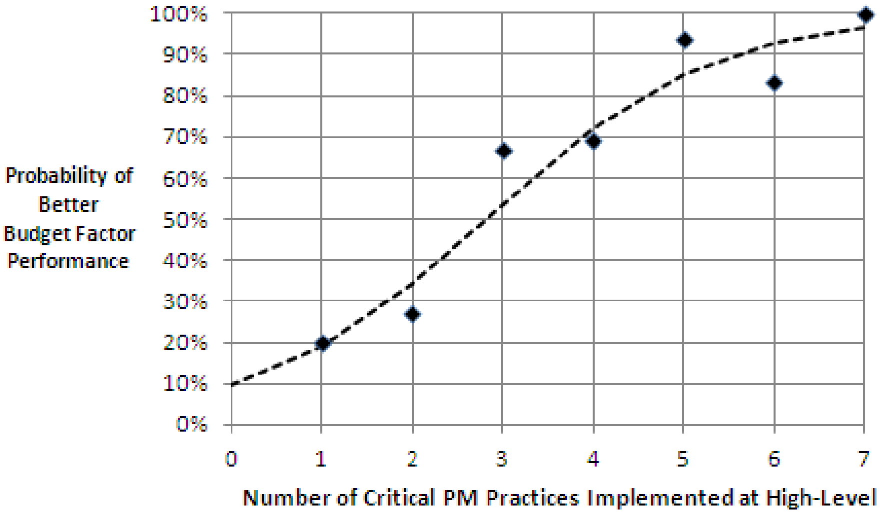
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	14	7	66.7
		Better	2	43	95.6
	Overall Percentage				86.4

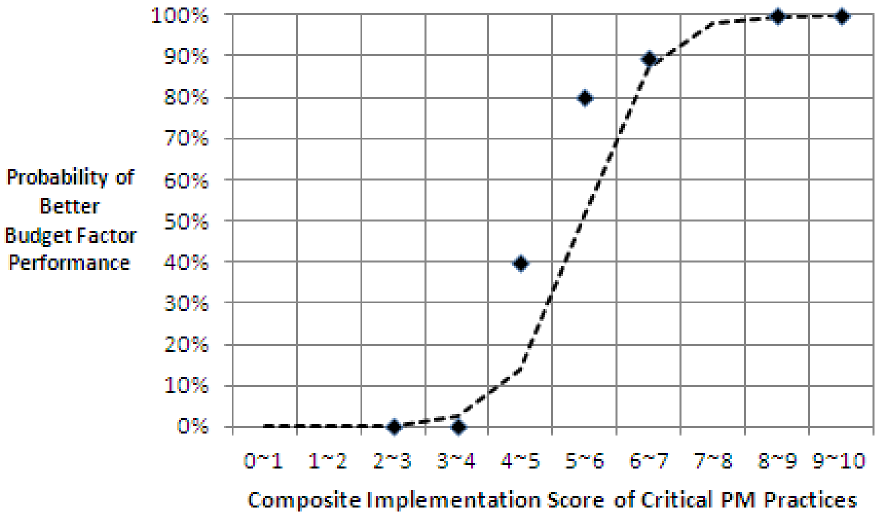
Figure 4.29: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Budget Factor Performance

Figure 4.30 represents changes in the probability of better budget factor performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better budget factor performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better budget factor performance. It can be suggested to implement five or more of the critical project management attributes implemented at high-level and make the composite implementation score over five because projects showed a higher probability of better budget factor performance in such implementation.

To sum up, this chapter identified seven critical project management attributes significantly related to budget factor performance when they were implemented with more than a certain level of effort (Table 4.24 and Table 4.25). The regression analyses arranged the seven critical project management attributes into their order of relative importance (Table 4.26). The combined effects of the seven project management attributes on budget factor performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.26 ~ Figure 4.30).



Number of Projects	Better	0	1	3	4	9	15	10	3
	Worse	0	4	8	2	4	1	2	0
	Total	0	5	11	6	13	16	12	3



Number of Projects	Better	0	0	0	0	2	16	25	0	1	1
	Worse	0	0	1	10	3	4	3	0	0	0
	Total	0	0	1	10	5	20	28	0	1	1

Figure 4.30: Probability of Better Budget Factor Performance by Two Indicators

4.2.2 SCHEDULE PERFORMANCE

Schedule performance was evaluated by using the schedule factor metric {Actual Total Project Duration / (Initial Planned Project Duration + Approved Change Duration)}. This metric measures schedule performance as a ratio of actual project duration to initial planned project duration with approved change duration. As described in Section 3.5.3, the schedule factor metric was preprocessed and categorized into two performance categories. Projects whose schedule factor metric was equal to or less than one were categorized into the better performance category, while projects whose schedule factor metric was greater than one were categorized into the worse performance category (Table 4.27).

Table 4.27: Schedule Factor Performance Category

	Better Performance Category	Worse Performance Category
Schedule Factor	< = 1	> 1

Identification of Minimum Implementation Levels for Project Management Attributes

For better schedule factor performance, Table 4.28 shows the minimum implementation levels for 16 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better schedule factor performance than projects implemented below the minimum level. By using the chi-square test and the Fisher's exact test, whether there is a statistically significant difference in the probabilities of better schedule factor performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better schedule factor performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.28: Minimum Implementation Level for Project Management Attributes for Better Schedule Factor Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Schedule Factor Performance
1	PDRI	7.9	*
2	FEP	6.7	*
3	Alignment	5.3	*
4	Partnering	7.3	
5	Team Building	5.8	
6	Change Management	8.5	*
7	Constructability	7.4	*
8	Project Risk Analysis	7.7	*
9	Planning for Startup	6.1	
10	Zero Accident Technique	8.6	
11	Timely Engineering Deliverables	7.2	
12	Accurate Engineering Deliverables	5.8	
13	Alliance	-	
14	Budget Accuracy	8.1	
15	Fast Track (Yes or No)	No	
16	Modularization	-	

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to schedule factor performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for schedule factor performance. As shown in Table 4.29, seven critical project management attributes for schedule factor performance were identified, including PDRI, FEP, alignment, change management, constructability, project risk assessment and budget accuracy.

Table 4.29: Critical Project Management Attributes for Schedule Factor Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI	*	*	*	*
2	FEP	*	*	*	*
3	Alignment	*	*	*	*
4	Partnering				
5	Team Building				
6	Change Management	*	*	*	*
7	Constructability	*	*	*	*
8	Project Risk Assessment	*	*	*	*
9	Planning for Startup				
10	Zero Accident Technique				
11	Timely Engineering Deliverables				
12	Accurate Engineering Deliverables				
13	Alliance				
14	Budget Accuracy	*	*	*	*
15	Fast-track				
16	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the seven critical project management attributes for better schedule factor performance, as discussed in Section 3.5.7. For the seven critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better schedule factor performance. The ranks of the three methods were averaged to generate an overall relative importance of the seven critical project management attributes, as shown in Table 4.30.

Table 4.30: Relative Importance of Critical Project Management Attributes for Better Schedule Factor Performance

	Project management Attribute (High- or Low-Level Implementation Group)	Linear		Logit		Probit		Overall	
		Coeff.	Rank	Coeff.	Rank	Coeff.	Rank	Rank Average	Rank
1	Constructability (High: >=7.4, Low: <7.4)	0.456	1	3.838	2	2.337	2	1.67	1
1	Project Risk Assessment (High: >=7.7, Low: <7.7)	0.358	3	3.982	1	2.472	1	1.67	1
3	PDRI (High: >=7.9, Low: <7.9)	0.383	2	1.804	4	1.068	4	3.33	3
3	Alignment (High: >=5.3, Low: <5.3)	0.212	4	2.025	3	1.208	3	3.33	3
5	Budget Accuracy (High: >=8.1, Low: <8.1)	0.118	5	0.925	5	0.538	5	5.00	5
6	Change Management (High: >=8.5, Low: <8.5)	0.036	6	-0.120	6	0.105	6	6.00	6
7	FEP (High: >=6.7, Low: <6.7)	-0.126	7	-0.864	7	-0.500	7	7.00	7

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the constructability attribute ranked first, which indicates that the implementation of this attribute with a score of 7.4 or above was the most important project management attribute for better schedule factor performance. However, it should be noted that the constructability attribute might not be the most important project management attribute when implemented with less than 7.4.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better schedule factor performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better schedule factor performance. Nonetheless, since all of the seven critical project management attributes were significantly related to schedule factor performance, the implementation of them all would be the best way to expect higher probability of better schedule factor performance.

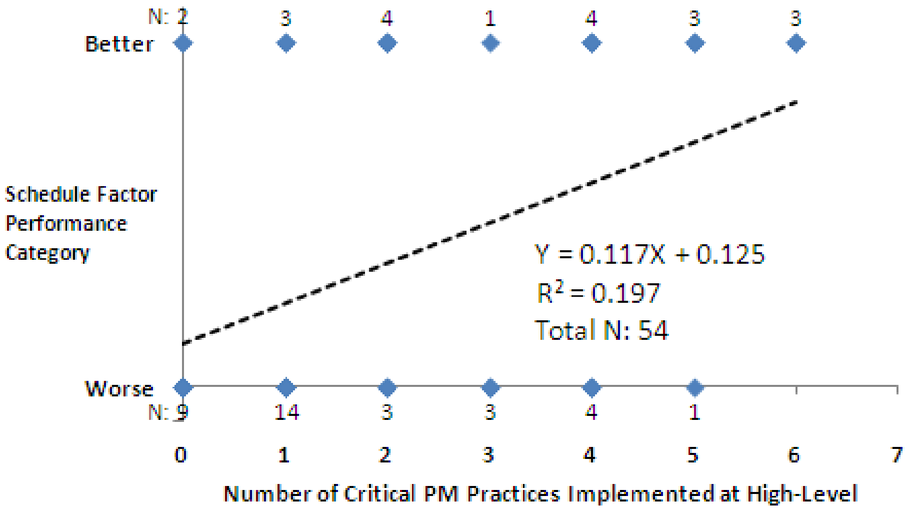
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on schedule factor performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the seven critical project management attributes for schedule factor performance were grouped into low-level or high-level as shown in Table 4.30, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and schedule factor performance was examined. Figure 4.31 and Figure 4.32 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.31 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of schedule factor performance (B=0.117, P-value=0.001). The fitted regression equation (Y = 0.117X + 0.125) also indicated a good model fit (F=12.735, P-value =0.001) and correctly classified 72.2% of 54 contractor projects for the schedule factor performance category. The equation implies that contractor projects could achieve better schedule factor performance (Y>0.5) when they executed four or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.117	.033	.444	3.569	.001
(Constant)	.125	.091		1.373	.176

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.477	1	2.477	12.735	0.001
Residual	10.115	52	.195		
Total	12.593	53			

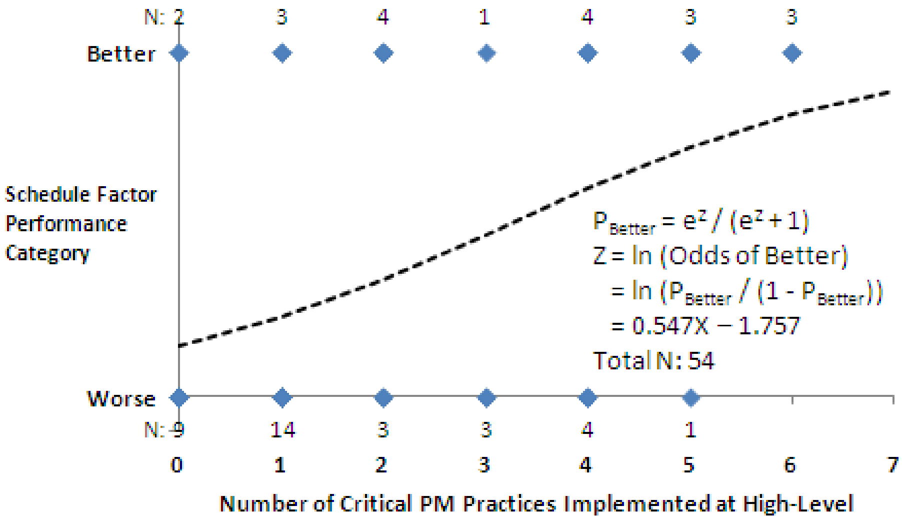
R	R Square	Adjusted R Square
0.444	.197	.181

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	29	5	85.3
		Better	10	10	50.0
	Overall Percentage				72.2

Figure 4.31: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Schedule Factor Performance

The logit regression analysis results provided in Figure 4.32 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of schedule factor performance (B=0.547, P-value=0.003). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 72.2% of 54 contractor projects were correctly classified for the schedule factor performance category. The fitted logit regression equation ($P_{Better} = e^{(0.547X-1.757)} / (e^{(0.547X-1.757)}+1)$ implies that the odds of better schedule factor performance were increased by a multiplicative factor of 1.727 ($=e^{(0.547)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that contractor projects could achieve better schedule factor performance (Y>0.5) when they executed four or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.692	.211	10.696	1.000	.001	1.997
(Constant)	-1.732	.495	12.244	1.000	.000	.177

Model Fit

	Chi-square	df	Sig.
Hosmer and Lemeshow Test	2.345	4	.673

Cox & Snell R Square	Nagelkerke R Square
.227	.309

Classification Table

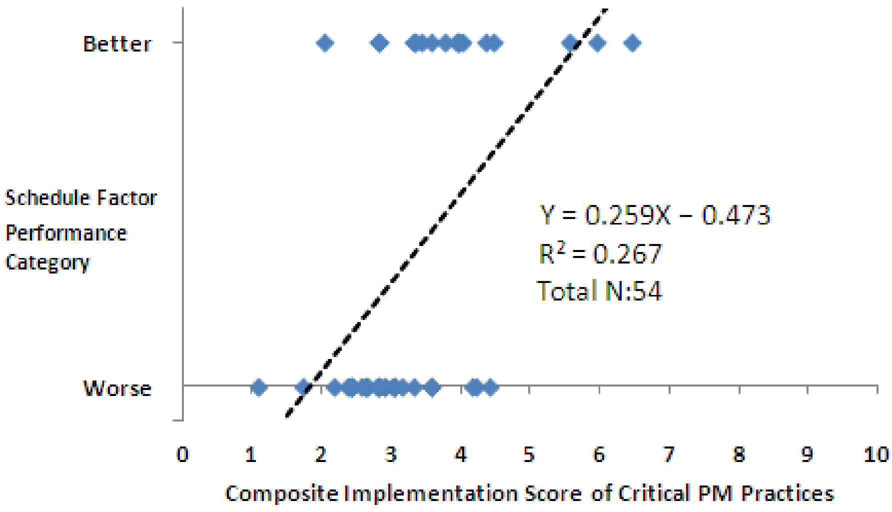
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	28	6	82.4
		Better	9	11	55.0
	Overall Percentage				72.2

Figure 4.32: Logit Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Schedule Factor Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on schedule factor performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.33 and 4.34 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.34 shows that the composite implementation score was a significant predictor of schedule factor performance (B=0.259, P-value=0.000). The fitted regression equation (Y = 0.221X − 0.316) also indicated a good model fit (F=18.964, P-value =0.000) and correctly classified 77.8% of 54 contractor projects for the schedule factor performance category. The equation implies that that contractor projects could achieve better schedule factor performance (Y>0.5) when their composite implementation score was equal or more than 3.75.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.259	.060	.517	4.355	.000
(Constant)	-.473	.202		-2.342	.023

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.365	1	3.365	18.964	0.000
Residual	9.227	52	.177		
Total	12.593	53			

R	R Square	Adjusted R Square
0.517	.267	.253

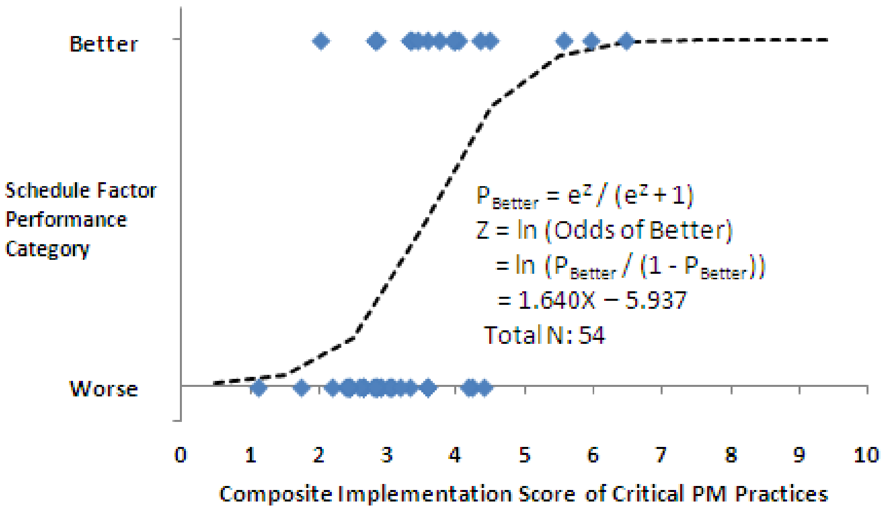
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	31	3	91.2
		Better	9	11	55.0
	Overall Percentage				77.8

Figure 4.33: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Schedule Factor Performance

The logit regression analysis results provided in Figure 4.34 also indicates that the composite implementation score was a highly significant predictor of schedule factor performance (B=1.640, P-value=0.002). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 77.8% of 54 contractor projects were correctly classified for the schedule factor performance category. The fitted regression equation ($P_{Better} = e^{(1.640X-5.937)} / (e^{(1.640X-5.937)}+1)$) implies that the odds of better schedule factor performance were increased by a multiplicative factor of 5.157 (=$e^{(1.640)}$) for every one point increase in the composite implementation score. It also indicates that contractor projects could achieve better schedule factor performance (Y>0.5) when the composite implementation score of the critical project management attributes were 3.62 or above.

Using OLS regression and logit regression, schedule factor performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with schedule factor performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that schedule factor performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	1.640	.520	9.946	1.000	.002	5.157
(Constant)	-5.937	1.744	11.586	1.000	.001	.003

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	15.614	8	.048

Cox & Snell R Square	Nagelkerke R Square
.269	.367

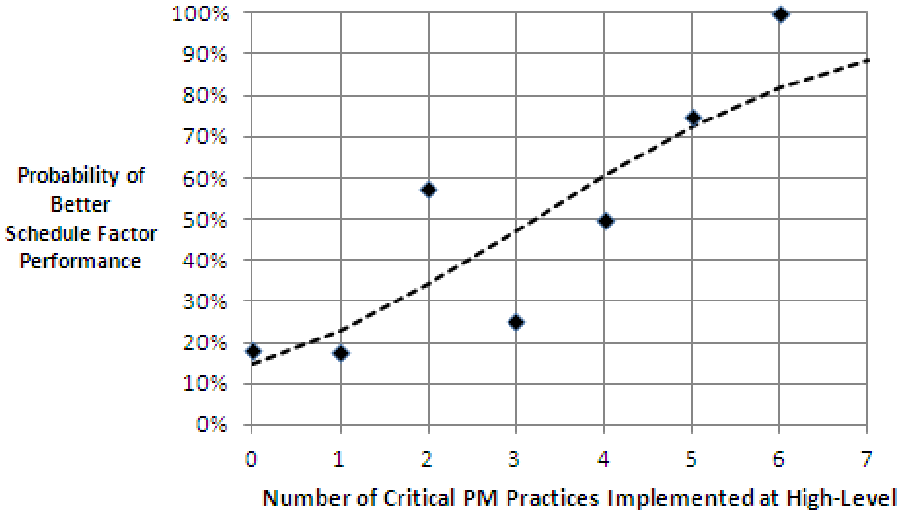
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	31	3	91.2
		Better	9	11	55.0
	Overall Percentage				77.8

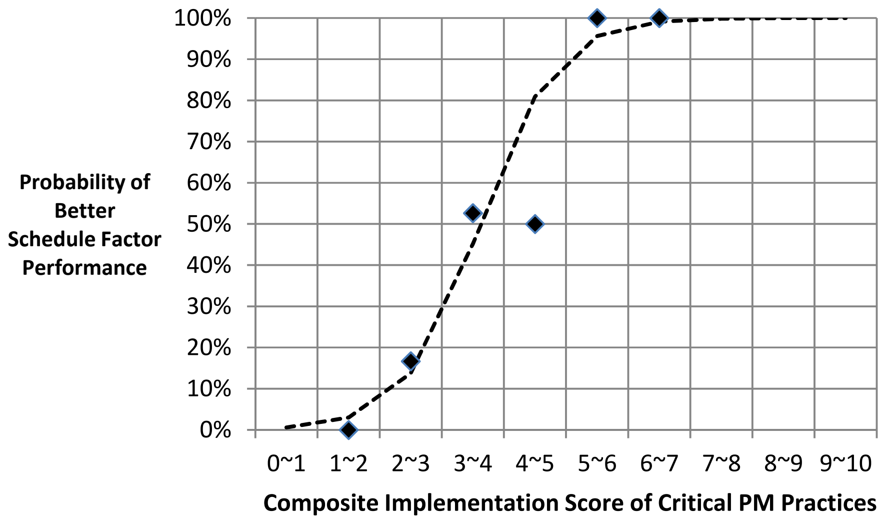
Figure 4.34: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Schedule Factor Performance

Figure 4.35 represents changes in the probability of better schedule factor performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better schedule factor performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better schedule factor performance. It can be suggested to implement five or more of the critical project management attributes implemented at high-level and make the composite implementation score over six because projects showed a higher probability of better schedule factor performance in such implementation.

To sum up, this chapter identified seven critical project management attributes significantly related to schedule factor performance when they were implemented with more than a certain level of effort (Table 4.24 and Table 4.25). The regression analyses arranged the seven critical project management attributes into their order of relative importance (Table 4.26). The combined effects of the seven project management attributes on schedule factor performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.26 ~ Figure 4.30).



Number of Projects	Better	2	3	4	1	4	3	3	0
	Worse	9	14	3	3	4	1	0	0
	Total	11	17	7	4	8	4	3	0



Number of Projects	Better	0	0	4	10	3	2	1	0	0	0
	Worse	0	2	20	9	3	0	0	0	0	0
	Total	0	2	24	19	6	2	1	0	0	0

Figure 4.35: Probability of Better Schedule Factor Performance by Two Indicators

4.2.3 SAFETY PERFORMANCE

Safety performance was evaluated by a survey question asking the level of satisfaction of safety goals. The question used a seven point Likert-scale in which one means “not at all successful” and seven means “extremely successful”. As described in Section 3.5.3, the level of satisfaction of safety goals was categorized into two performance categories. Projects whose level of satisfaction of safety goals was seven were categorized into the better performance category, while projects whose level of satisfaction of safety goals was six or below were categorized into the worse performance category (Table 4.31).

Table 4.31: Safety Performance Category

	Better Performance Category	Worse Performance Category
Safety Performance	Extremely Successful	Other

Identification of Minimum Implementation Levels for Project Management Attributes

For better safety performance, Table 4.32 shows the minimum implementation levels for 16 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better safety performance than projects implemented below the minimum level. By using the chi-square test and the Fisher’s exact test, whether there is a statistically significant difference in the probabilities of better safety performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better safety performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.32: Minimum Implementation Level for Project Management Attributes for Better Safety Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Safety Performance
1	PDRI	8.2	
2	FEP	7.0	*
3	Alignment	5.8	*
4	Partnering	5.1	*
5	Team Building	7.4	*
6	Change Management	7.7	*
7	Constructability	5.3	*
8	Project Risk Analysis	1.3	
9	Planning for Startup	4.9	
10	Zero Accident Technique	7.2	
11	Timely Engineering Deliverables	4.3	
12	Accurate Engineering Deliverables	4.3	
13	Alliance	-	
14	Budget Accuracy	-	
15	Fast Track (Yes or No)	No	
16	Modularization	1.1	

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to safety performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for safety performance. As shown in Table 4.11, six critical project management attributes for safety performance were identified, including FEP, alignment, partnering, team building, change management, and constructability.

Table 4.33: Critical Project Management Attributes for Safety Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI				
2	FEP	*	*	*	*
3	Alignment	*	*	*	*
4	Partnering	*	*	*	*
5	Team Building	*	*	*	*
6	Change Management	*	*	*	*
7	Constructability	*	*	*	*
8	Project Risk Assessment				
9	Planning for Startup				
10	Zero Accident Technique				
11	Timely Engineering Deliverables				
12	Accurate Engineering Deliverables				
13	Alliance				
14	Budget Accuracy				
15	Fast-track				
16	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the six critical project management attributes for better safety performance, as discussed in Section 3.5.7. For the six critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better safety performance. The ranks of the three methods were averaged to generate an overall relative importance of the six critical project management attributes, as shown in Table 4.34.

Table 4.34: Relative Importance of Critical Project Management Attributes for Better Safety Performance

	Project Management Attribute (High- or Low-Level Implementation Group)	Linear		Logit		Probit		Overall	
		Coef	Rank	Coef	Rank	Coef	Rank	Rank Average	Rank
1	Alignment (High: >=5.8, Low: <5.8)	0.319	1	1.929	1	1.120	1	1.00	1
2	Partnering (High: >=5.1, Low: <5.1)	0.220	3	1.294	2	0.611	4	3.00	2
3	Team Building (High: >=7.4, Low: <7.4)	0.221	2	1.221	4	0.673	3	3.00	2
4	Constructability (High: >=5.3, Low: <5.3)	0.204	4	1.287	3	0.724	2	3.00	2
5	Change Management (High: >=7.7, Low: <7.7)	0.191	5	0.974	5	0.596	5	5.00	5
6	FEP (High: >=7.0, Low: <7.0)	-0.001	6	-0.188	6	-0.051	6	6.00	6

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the alignment attribute ranked first, which indicates that the implementation of this attribute with a score of 5.8 or above was the most important project management attribute for better safety performance. However, it should be noted that the alignment attribute might not be the most important project management attribute when implemented with less than 5.8.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better safety performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better safety performance. Nonetheless, since all of the six critical project management attributes were significantly related to safety performance, the implementation of them all would be the best way to expect higher probability of better safety performance.

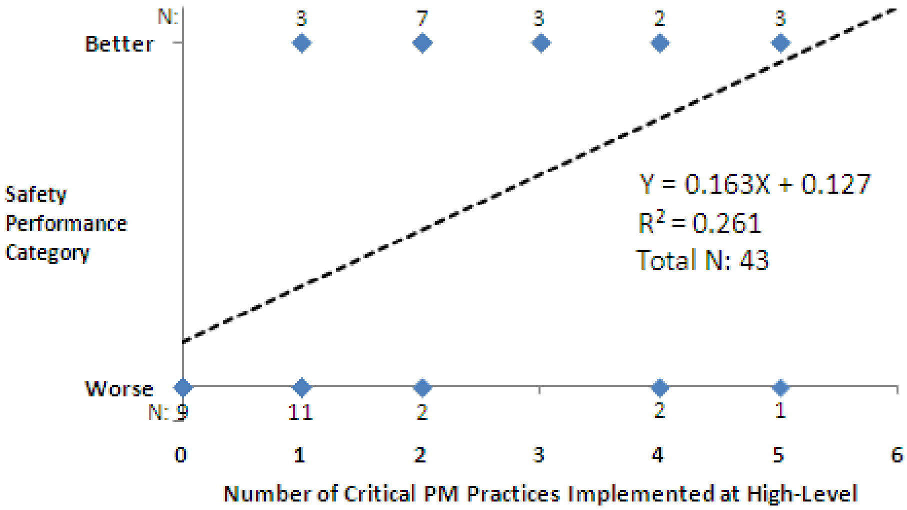
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on safety performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the six critical project management attributes for safety performance were divided into low-level or high-level as shown in Table 4.34, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and safety performance was examined. Figure 4.36 and Figure 4.37 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.36 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of safety performance (B=0.163, P-value=0.000). The fitted regression equation ($Y = 0.163X + 0.127$) also indicated a good model fit (F=14.445, P-value =0.000) and correctly classified 69.8% of 43 contractor projects for the safety performance category. The equation implies that contractor projects could achieve better safety performance ($Y>0.5$) when they executed three or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.163	.043	.510	3.801	.000
(Constant)	.127	.101		1.258	.215

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.727	1	2.727	14.445	0.000
Residual	7.739	41	.189		
Total	10.465	42			

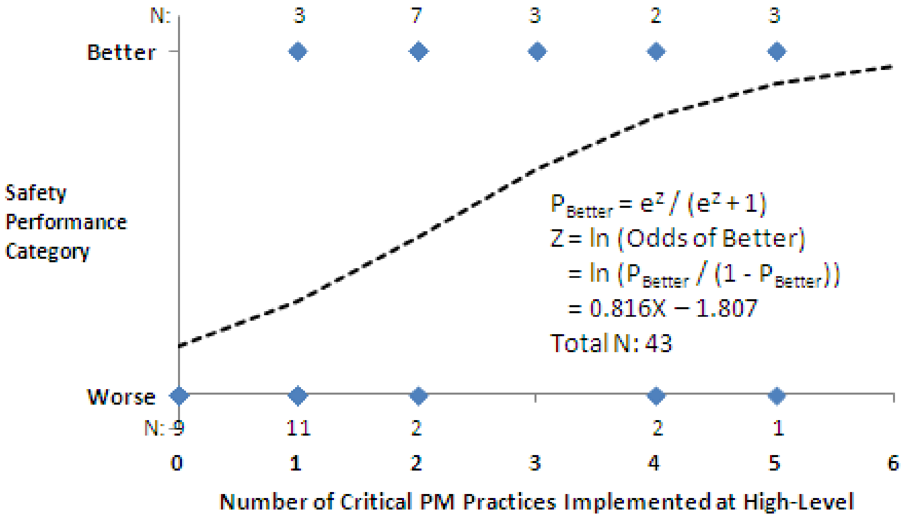
R	R Square	Adjusted R Square
0.510	.261	.242

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	22	3	88.0
		Better	10	8	44.4
	Overall Percentage				69.8

Figure 4.36: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Safety Performance

The logit regression analysis results provided in Figure 4.37 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of safety performance (B=0.816, P-value=0.004). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 69.8% of 43 contractor projects were correctly classified for the safety performance category. The fitted logit regression equation ($P_{Better} = e^{(0.816X-1.807)} / (e^{(0.816X-1.807)}+1)$ implies that the odds of better safety performance were increased by a multiplicative factor of 2.260 ($=e^{(0.816)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that contractor projects could achieve better safety performance (Y>0.5) when they executed three or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.816	.280	8.500	1.000	.004	2.260
(Constant)	-1.807	.605	8.919	1.000	.003	.164

Model Fit

	Chi-square	df	Sig.
Hosmer and Lemeshow Test	10.712	4	.030

Cox & Snell R Square	Nagelkerke R Square
.246	.331

Classification Table

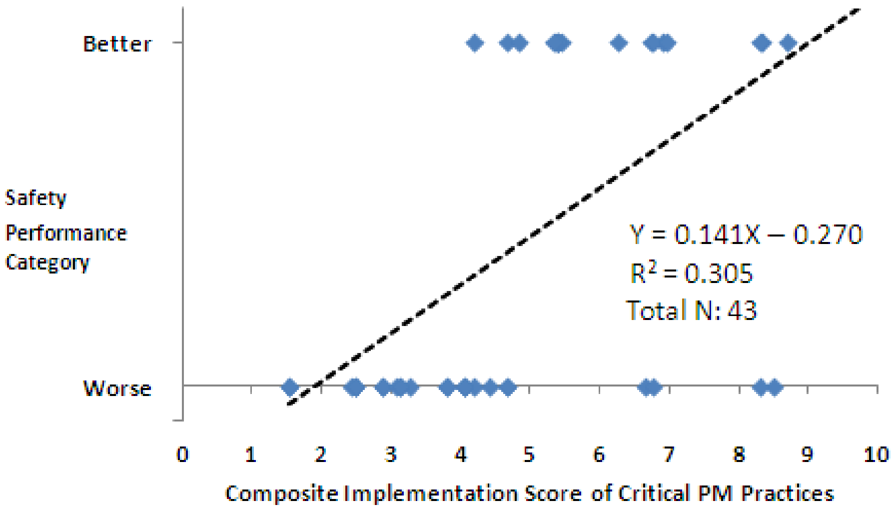
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	22	3	88.0
		Better	10	8	44.4
	Overall Percentage				69.8

Figure 4.37: Logit Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Safety Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on safety performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.38 and 4.39 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.38 shows that the composite implementation score was a significant predictor of safety performance (B=0.141, P-value=0.000). The fitted regression equation ($Y = 0.141X - 0.270$) also indicated a good model fit (F=17.974, P-value =0.000) and correctly classified 67.4% of 43 contractor projects for the safety performance category. The equation implies that that contractor projects could achieve better safety performance ($Y>0.5$) when their composite implementation score was equal or more than 5.45.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.141	.033	.552	4.240	.000
(Constant)	-.270	.175		-1.544	.130

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.190	1	3.190	17.974	0.000
Residual	7.276	41	.177		
Total	10.465	42			

R	R Square	Adjusted R Square
0.552	.305	.288

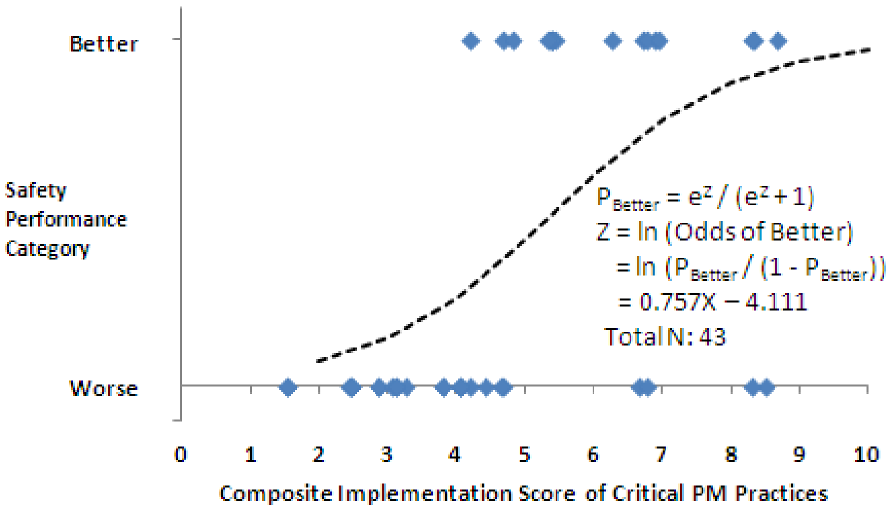
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	21	4	84.0
		Better	10	8	44.4
	Overall Percentage				67.4

Figure 4.38: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Safety Performance

The logit regression analysis results provided in Figure 4.39 also indicates that the composite implementation score was a highly significant predictor of safety performance (B=0.757, P-value=0.002). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 69.8% of 43 contractor projects were correctly classified for the safety performance category. The fitted regression equation ($P_{Better} = e^{(0.757X-4.111)}/(e^{(0.757X-4.111)}+1)$) implies that the odds of better safety performance were increased by a multiplicative factor of 2.132 ($=e^{(0.757)}$) for every one point increase in the composite implementation score. It also indicates that contractor projects could achieve better safety performance (Y>0.5) when the composite implementation score of the critical project management attributes were 5.43 or above.

Using OLS regression and logit regression, safety performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with safety performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that safety performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.757	.243	9.679	1.000	.002	2.132
(Constant)	-4.111	1.279	10.331	1.000	.001	.016

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	16.155	8	.040

Cox & Snell R Square	Nagelkerke R Square
.290	.391

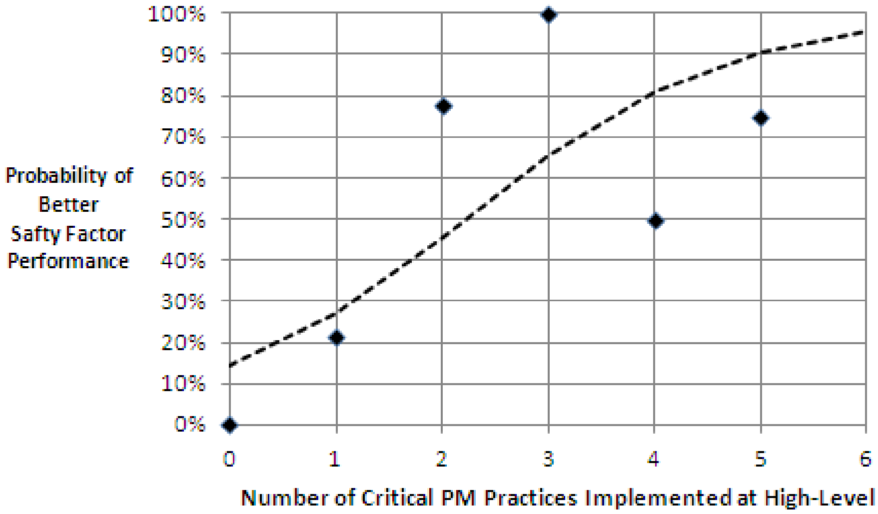
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	21	4	84.0
		Better	9	9	50.0
	Overall Percentage				69.8

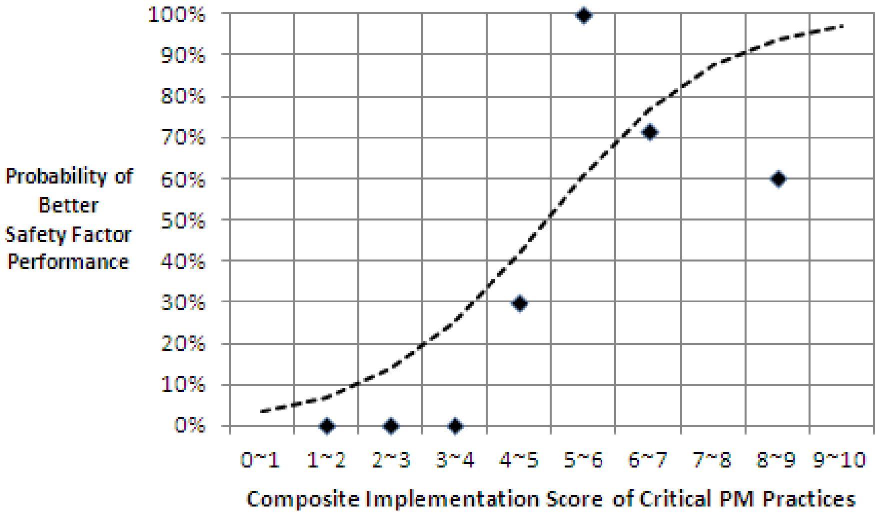
Figure 4.39: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Cost Growth Performance

Figure 4.40 represents changes in the probability of better safety performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better safety performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better safety performance. It can be suggested to implement two or more of the critical project management attributes at high-level and make the composite implementation score over five because projects showed a higher probability of better cost growth performance in such implementation.

To sum up, this chapter identified six critical project management attributes significantly related to safety performance when they were implemented with more than a certain level of effort (Table 4.22 and Table 4.33). The regression analyses arranged the six critical project management attributes into their order of relative importance (Table 4.34). The combined effects of the six project management attributes on safety performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.36 ~ Figure 4.40).



Number of Projects								
	Better	0	3	7	3	2	3	0
	Worse	9	11	2	0	2	1	0
	Total	9	14	9	3	4	4	0



Number of Projects											
	Better	0	0	0	0	3	7	5	0	3	0
	Worse	0	2	6	6	7	0	2	0	2	0
	Total	0	2	6	6	10	7	7	0	5	0

Figure 4.40: Probability of Better Safety Performance by Two Indicators

4.2.4 QUALITY PERFORMANCE

Quality performance was evaluated by a survey question asking the level of satisfaction of quality goals. The question used a seven point Likert-scale in which one means "not at all successful" and seven means "extremely successful". As described in Section 3.5.3, the level of satisfaction of quality goals was categorized into two performance categories. Projects whose level of satisfaction of quality goals was seven were categorized into the better performance category, while projects whose level of satisfaction of quality goals was six or below were categorized into the worse performance category (Table 4.35).

Table 4.35: Quality Performance Category

	Better Performance Category	Worse Performance Category
Quality Performance	Extremely Successful	Other

Identification of Minimum Implementation Levels for Project Management Attributes

For better quality performance, Table 4.36 shows the minimum implementation levels for 16 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better quality performance than projects implemented below the minimum level. By using the chi-square test and the Fisher's exact test, whether there is a statistically significant difference in the probabilities of better quality performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better safety performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.36: Minimum Implementation Level for Project Management Attributes for Better Quality Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Quality Performance
1	PDRI	8.2	*
2	FEP	5.8	*
3	Alignment	4.2	*
4	Partnering	0.1	
5	Team Building	7.4	
6	Change Management	8.6	
7	Constructability	6.3	
8	Project Risk Analysis	-	
9	Planning for Startup	6.5	*
10	Zero Accident Technique	7.1	
11	Timely Engineering Deliverables	5.8	*
12	Accurate Engineering Deliverables	5.8	
13	Alliance	-	
14	Budget Accuracy	8.1	
15	Fast Track (Yes or No)	Yes	
16	Modularization	1.1	

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to quality performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for quality performance. As shown in Table 4.37, five critical project management attributes for quality performance were identified, including PDRI, FEP, alignment, planning for startup, and timely engineering deliverables.

Table 4.37: Critical Project Management Attributes for Quality Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI	*	*	*	*
2	FEP	*	*	*	*
3	Alignment	*	*	*	*
4	Partnering				
5	Team Building				
6	Change Management				
7	Constructability				
8	Project Risk Assessment				
9	Planning for Startup	*	*	*	*
10	Zero Accident Technique				
11	Timely Engineering Deliverables	*	*	*	*
12	Accurate Engineering Deliverables				
13	Alliance				
14	Budget Accuracy				
15	Fast-track				
16	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the five critical project management attributes for better quality performance, as discussed in Section 3.5.7. For the five critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better quality performance. The ranks of the three methods were averaged to generate an overall relative importance of the five critical project management attributes, as shown in Table 4.38.

Table 4.38: Relative Importance of Critical Project Management Attributes for Better Quality Performance

	Project management Attribute (High- or Low-Level Implementation Group)	Linear		Logit		Probit		Overall	
		Coeff.	Rank	Coeff.	Rank	Coeff.	Rank	Rank Average	Rank
1	FEP (High: >=5.8, Low: <5.8)	0.251	3	3.973	1	2.354	1	1.67	1
2	Alignment (High: >=4.2, Low: <4.2)	0.337	1	2.465	2	1.435	3	2.00	2
3	PDRI (High: >=8.2, Low: <8.2)	0.295	2	2.127	3	1.441	2	2.33	3
4	Timely Engineering Deliverables (High: >=5.8 Low: <5.8)	0.174	4	1.220	4	0.799	4	4.00	4
5	Planning for Startup (High: >=6.5, Low: <6.5)	0.117	5	-0.539	5	-0.305	5	5.00	5

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the FEP attribute ranked first, which indicates that the implementation of this attribute with a score of 5.8 or above was the most important project management attribute for better quality performance. However, it should be noted that the FEP attribute might not be the most important project management attribute when implemented with less than 5.8.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better quality performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better quality performance. Nonetheless, since all of the five critical project management attributes were significantly related to quality performance, the implementation of them all would be the best way to expect higher probability of better quality performance.

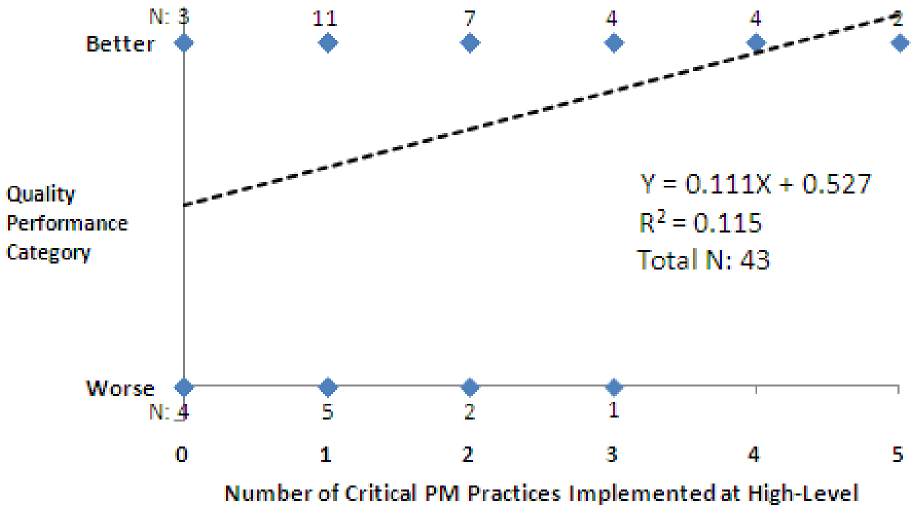
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on quality performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the 5 critical project management attributes for quality performance were divided into low-level or high-level as shown in Table 4.38, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and quality performance was examined. Figure 4.41 and Figure 4.42 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.41 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of quality performance (B=0.111, P-value=0.026). The fitted regression equation (Y = 0.111X + 0.527) also indicated a good model fit (F=5.326, P-value =0.026) and correctly classified 50.0% of 43 contractor projects for the quality performance category. The equation implies that contractor projects could achieve better quality performance (Y>0.5) when they executed zero or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.111	.048	.339	2.308	.026
(Constant)	.527	.107		4.927	.000

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.995	1	.995	5.326	0.026
Residual	7.657	41	.187		
Total	8.651	42			

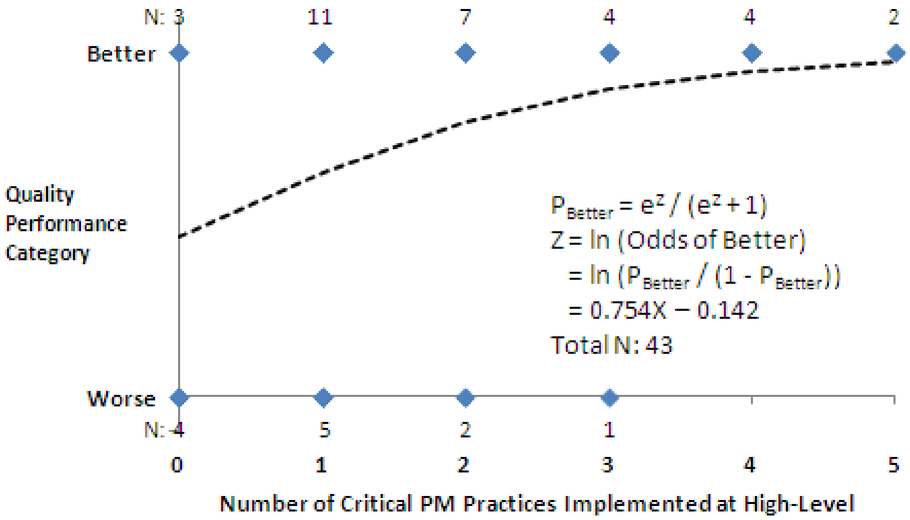
R	R Square	Adjusted R Square
0.339	.115	.093

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	12	12	50.0
		Better	31	31	50.0
	Overall Percentage				50.0

Figure 4.41: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Quality Performance

The logit regression analysis results provided in Figure 4.42 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of quality performance (B=0.754, P-value=0.040). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 74.4% of 43 contractor projects were correctly classified for the quality performance category. The fitted logit regression equation ($P_{Better} = e^{(0.754X-0.141)} / (e^{(0.754X-0.141)}+1)$ implies that the odds of better quality performance were increased by a multiplicative factor of 2.126 ($=e^{(0.754)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that contractor projects could achieve better quality performance (Y>0.5) when they executed one or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.754	.366	4.235	1.000	.040	2.126
(Constant)	-.141	.569	.062	1.000	.804	.868

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	.894	4	.925

Cox & Snell R Square	Nagelkerke R Square
.127	.184

Classification Table

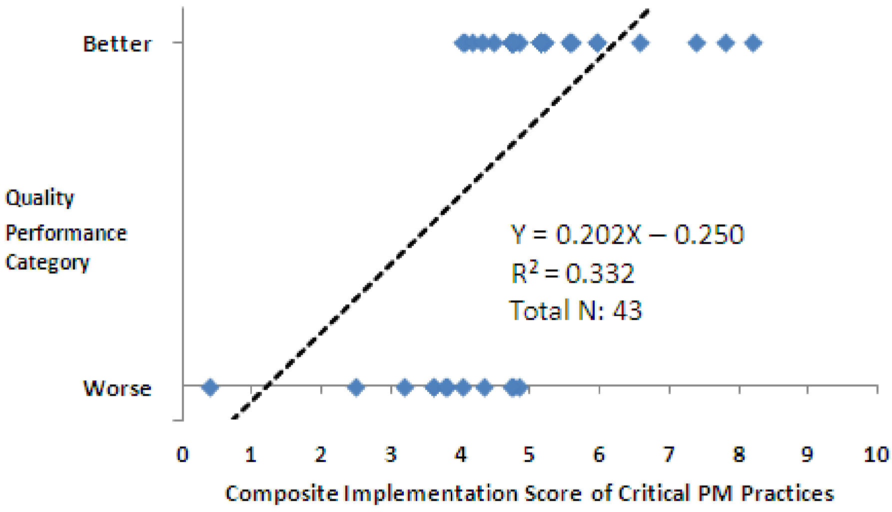
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	4	8	33.3
		Better	3	28	90.3
	Overall Percentage				74.4

Figure 4.42: Logit Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Quality Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on quality performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.43 and 4.44 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.43 shows that the composite implementation score was a significant predictor of quality performance (B=0.202, P-value=0.000). The fitted regression equation ($Y = 0.202X - 0.250$) also indicated a good model fit (F=20.330, P-value =0.000) and correctly classified 83.7% of 43 contractor projects for the quality performance category. The equation implies that that contractor projects could achieve better quality performance ($Y>0.5$) when their composite implementation score was equal or more than 3.72.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.202	.045	.576	4.509	.000
(Constant)	-.250	.223		-1.121	.269

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.868	1	2.868	20.330	0.000
Residual	5.783	41	.141		
Total	8.651	42			

R	R Square	Adjusted R Square
0.576	.331	.315

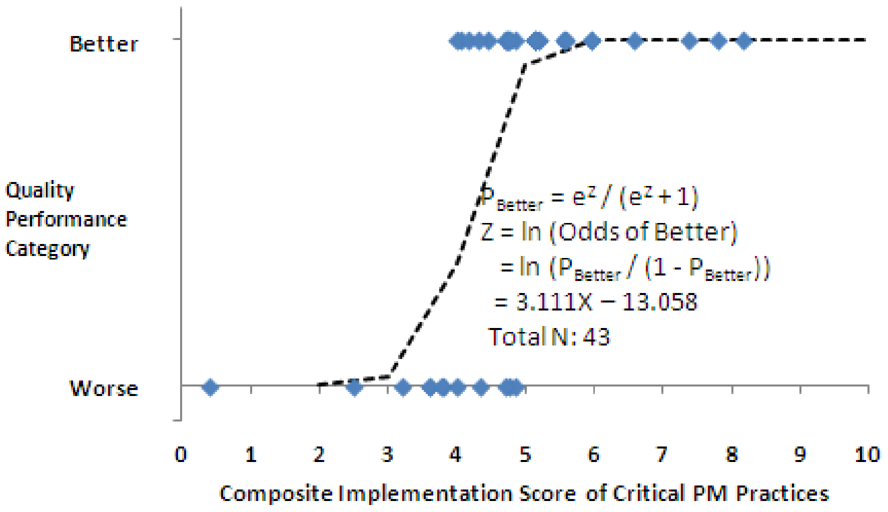
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	5	7	41.7
		Better	0	31	100.0
	Overall Percentage				83.7

Figure 4.43: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Quality Performance

The logit regression analysis results provided in Figure 4.44 also indicates that the composite implementation score was a highly significant predictor of quality performance (B=3.111, P-value=0.002). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 83.7% of 43 contractor projects were correctly classified for the quality performance category. The fitted regression equation ($P_{Better} = e^{(3.111X-13.058)}/ (e^{(3.111X-13.058)}+1)$ implies that the odds of better quality performance were increased by a multiplicative factor of 22.435 ($=e^{(3.111)}$) for every one point increase in the composite implementation score. It also indicates that contractor projects could achieve better quality performance (Y>0.5) when the composite implementation score of the critical project management attributes were 4.20 or above.

Using OLS regression and logit regression, quality performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with quality performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that quality performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	3.111	1.026	9.184	1.000	.002	22.435
(Constant)	-13.058	4.564	8.188	1.000	.004	.000

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	5.485	8	.705

Cox & Snell R Square	Nagelkerke R Square
.424	.611

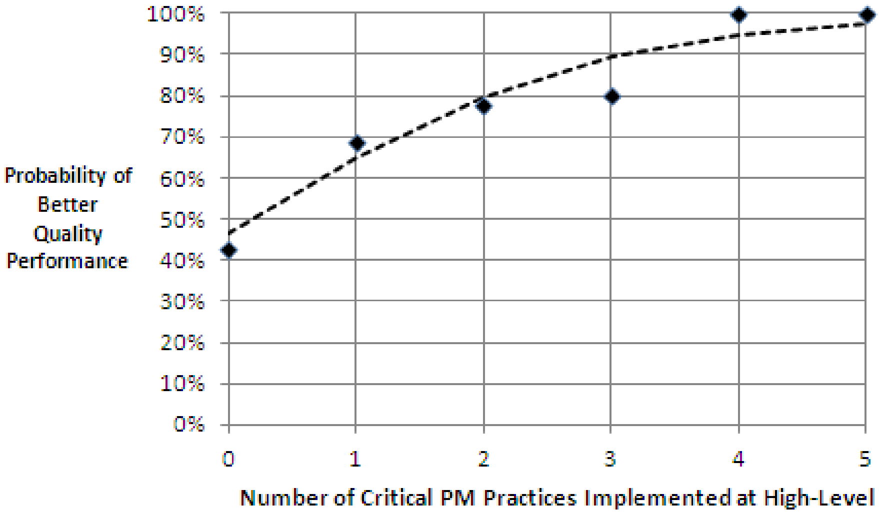
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	8	4	66.7
		Better	3	28	90.3
	Overall Percentage				83.7

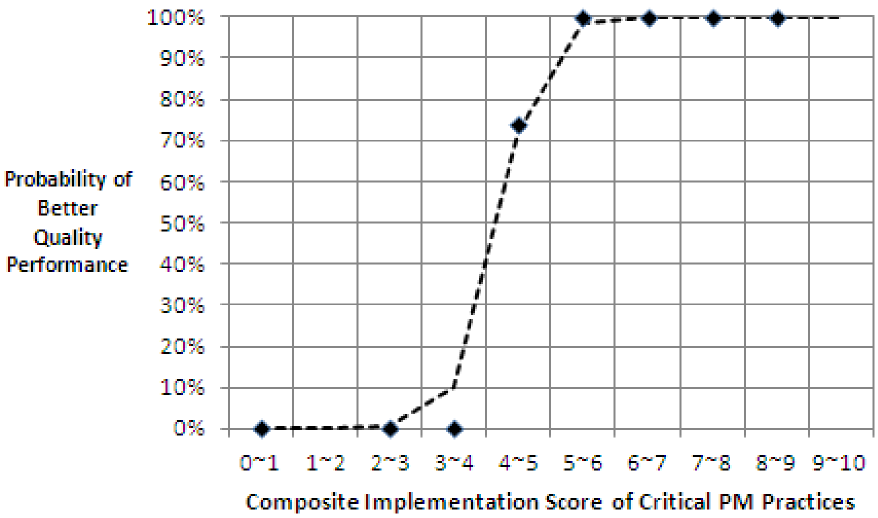
Figure 4.44: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Cost Growth Performance

Figure 4.45 represents changes in the probability of better quality performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better quality performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better quality performance. It can be suggested to implement three or more of the critical project management attributes at high-level and make the composite implementation score over five because projects showed a higher probability of better cost growth performance in such implementation.

To sum up, this chapter identified five critical project management attributes significantly related to quality performance when they were implemented with more than a certain level of effort (Table 4.36 and Table 4.37). The regression analyses arranged the 5 critical project management attributes into their order of relative importance (Table 4.38). The combined effects of the five project management attributes on quality performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.41 ~ Figure 4.45).



Number of Projects	Better	3	11	7	4	4	2
	Worse	4	5	2	1	0	0
	Total	7	16	9	5	4	2



Number of Projects	Better	0	0	0	0	14	13	1	2	1	0
	Worse	1	0	1	5	5	0	0	0	0	0
	Total	1	0	1	5	19	13	1	2	1	0

Figure 4.45: Probability of Better Quality Performance by Two Indicators

4.2.5 BUSINESS PERFORMANCE

Business performance was evaluated by a survey question asking the level of satisfaction of business goals. The question used a seven point Likert-scale in which one means "not at all successful" and seven means "extremely successful". As described in Section 3.5.3, the level of satisfaction of business goals was categorized into two performance categories. Projects whose level of satisfaction of business goals was seven were categorized into the better performance category, while projects whose level of satisfaction of business goals was six or below were categorized into the worse performance category (Table 4.39).

Table 4.39: Business Performance Category

	Better Performance Category	Worse Performance Category
Business Performance	Extremely Successful	Other

Identification of Minimum Implementation Levels for Project Management Attributes

For better business performance, Table 4.40 shows the minimum implementation levels for 19 project management attributes produced by the contingency table analysis which was described in Section 3.5.4. The last column shows whether projects implemented over the minimum level had a significantly better business performance than projects implemented below the minimum level. By using the chi-square test and the Fisher's exact test, whether there is a statistically significant difference in the probabilities of better business performance between projects implemented at high-level and projects implemented at low-level. When the tests were significant at the 0.10 level or less, there was a considerably large difference in the probabilities of better business performance between projects with project management attributes implemented at high-level and projects with project management attributes implemented at low-level. The results produced by the contingency table analysis are listed in Appendix C.

Table 4.40: Minimum Implementation Level for Project Management Attributes for Better Business Performance

* Significance at α=0.10

	Project Management Attribute	Minimum Level	Significance of Better Quality Performance
1	PDRI	7.5	
2	FEP	8.1	
3	Alignment	4.7	*
4	Partnering	5.1	
5	Team Building	7.4	
6	Change Management	7.7	*
7	Constructability	3.0	
8	Project Risk Analysis	7.3	
9	Planning for Startup	-	
10	Zero Accident Technique	8.5	
11	Timely Engineering Deliverables	4.3	*
12	Accurate Engineering Deliverables	2.9	
13	Alliance	-	
14	Budget Accuracy	4.1	
15	Fast Track (Yes or No)	No	
16	Modularization	1.1	

Identification of Critical Project Management Attributes

As discussed in Section 3.5.6, three univariate regression analysis methods: OLS, logit, and probit were used to determine critical project management attributes that are significantly related to business performance. When the three regression methods simultaneously showed a significant test result at the 0.10 level, a project management attribute was regarded as a critical project management attribute for business performance. As shown in Table 4.41, three critical project management attributes for business performance were identified, including alignment, change management, and timely engineering.

Table 4.41: Critical Project Management Attributes for Business Performance

* Significance at α=0.10

	Project Management Attribute	OLS	Logit	Probit	Critical Project Management Attribute
1	PDRI				
2	FEP				
3	Alignment	*	*	*	*
4	Partnering				
5	Team Building				
6	Change Management	*	*	*	*
7	Constructability				
8	Project Risk Assessment				
9	Planning for Startup				
10	Zero Accident Technique				
11	Timely Engineering Deliverables	*	*	*	*
12	Accurate Engineering Deliverables				
13	Alliance				
14	Budget Accuracy				
15	Fast-track				
16	Modularization				

Relative Importance of Critical Project Management Attributes

With the three regression methods, multivariate analysis was conducted to determine the relative importance of the 3 critical project management attributes for better business performance, as discussed in Section 3.5.7. For the three critical project management attributes, their coefficient sizes produced from each regression method were compared and ranked. A greater coefficient indicates more relative importance of its effect for better business performance. The ranks of the three methods were averaged to generate an overall relative importance of the three critical project management attributes, as shown in Table 4.42.

Table 4.42: Relative Importance of Critical Project Management Attributes for Better Business Performance

	Project management Attribute (High- or Low-Level Implementation Group)	Linear		Logit		Probit		Overall	
		Coef	Rank	Coef	Rank	Coef	Rank	Rank Average	Rank
1	Timely Engineering Deliverables (High: >=4.3, Low: <4.3)	0.381	1	1.962	1	1.197	1	1.00	1
2	Alignment (High: >=4.7, Low: <4.7)	0.269	2	1.398	2	0.872	2	2.00	2
3	Change Management (High: >=7.7 Low: <7.7)	0.241	3	1.128	3	0.695	3	3.00	3

The overall relative ranks of the critical project management attributes requires considering their level of implementation. For example, the timely engineering deliverables attribute ranked first, which indicates that the implementation of this attribute with a score of 4.3 or above was the most important project management attribute for better business performance. However, it should be noted that the FEP attribute might not be the most important project management attribute when implemented with less than 4.3.

The overall relative ranks can be used as a reference for an effective implementation strategy of project management attributes for achieving better business performance. If a project has limited resources, it may be difficult to implement all of project management attributes. In that case, implementing the higher ranked critical project management attributes first can be the most effective way to increase the probability for achieving better business performance. Nonetheless, since all of the three critical project management attributes were significantly related to business performance, the implementation of them all would be the best way to expect higher probability of better business performance.

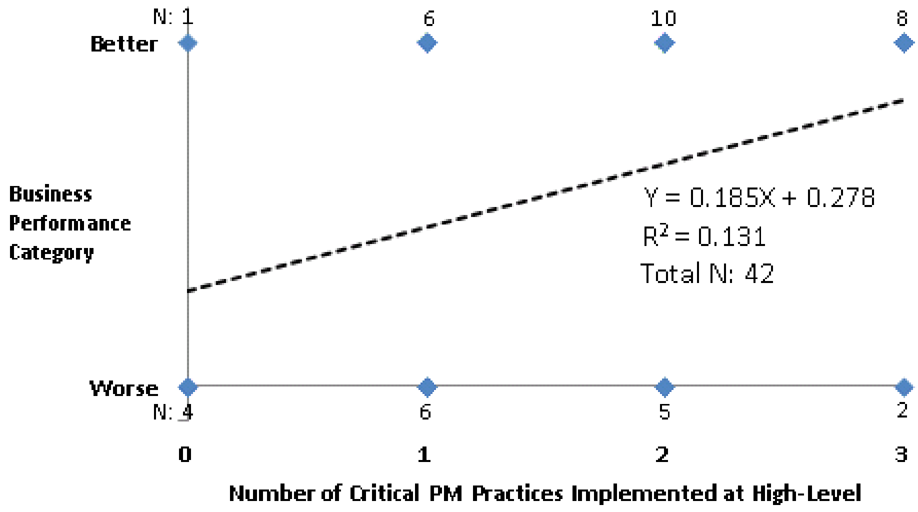
Analysis of the Combined Effects of Critical Project Management Attributes

The combined effects of critical project management attributes on business performance were analyzed from two perspectives: 1) the number of the critical project management attributes implemented at high-level and 2) a composite implementation score of the critical project management attributes.

Number of Critical Project Management Attributes Implemented at High-Level

Since the implementation levels of the 3 critical project management attributes for business performance were divided into low-level or high-level as shown in Table 4.42, the number of the critical project management attributes implemented at high-level could be counted for each project. Then, the relationship between the number of the critical project management attributes implemented at high-level and business performance was examined. Figure 4.46 and Figure 4.47 show the results analyzed using OLS and logit regression.

The OLS regression analysis results provided in Figure 4.46 shows that the number of the critical project management attributes implemented at high-level was a significant predictor of business performance (B=0.185, P-value=0.019). The fitted regression equation ($Y = 0.185X + 0.278$) also indicated a good model fit (F=6.015, P-value =0.019) and correctly classified 66.7% of 42 contractor projects for the business performance category. The equation implies that contractor projects could achieve better business performance ($Y>0.5$) when they executed two or more critical project management attributes implemented at high-level.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.185	.076	.362	2.453	.019
(Constant)	.278	.148		1.873	.068

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.323	1	1.323	6.015	0.019
Residual	8.796	40	.220		
Total	10.119	41			

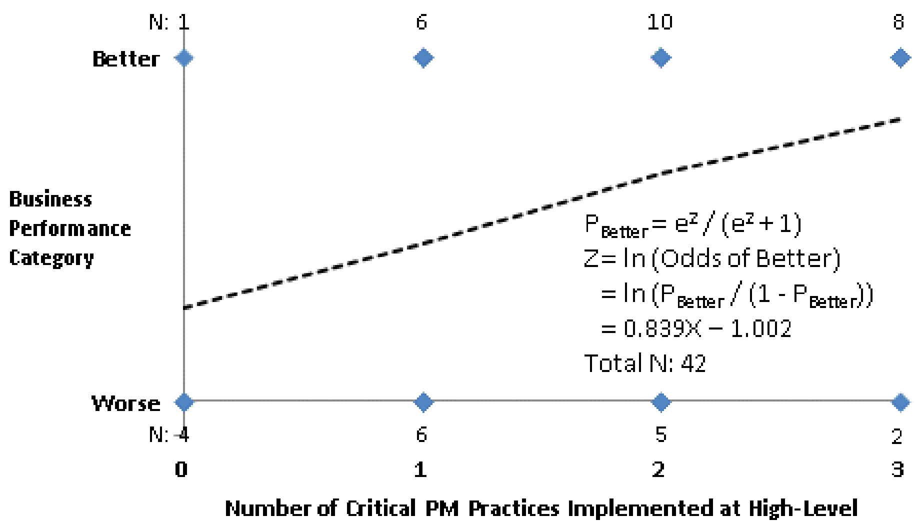
R	R Square	Adjusted R Square
0.362	.131	.109

Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	10	7	58.8
		Better	7	18	72.0
	Overall Percentage				66.7

Figure 4.46: Linear Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Business Performance

The logit regression analysis results provided in Figure 4.47 also indicates that the number of the critical project management attributes implemented at high-level was a highly significant predictor of business performance (B=0.839, P-value=0.026). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 66.7% of 42 contractor projects were correctly classified for the business performance category. The fitted logit regression equation ($P_{Better} = e^{(0.839X-1.002)} / (e^{(0.839X-1.002)}+1)$ implies that the odds of better business performance were increased by a multiplicative factor of 2.314 ($=e^{(0.839)}$) for every increase in the number of the critical project management attributes implemented at high-level. It also indicates that contractor projects could achieve better business performance (Y>0.5) when they executed two or more critical project management attributes implemented at high-level.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.839	.377	4.942	1.000	.026	2.314
(Constant)	-1.002	.694	2.086	1.000	.149	.367

Model Fit

	Chi-square	df	Sig.
Hosmer and Lemeshow Test	.227	2	.893

Cox & Snell R Square	Nagelkerke R Square
.127	.172

Classification Table

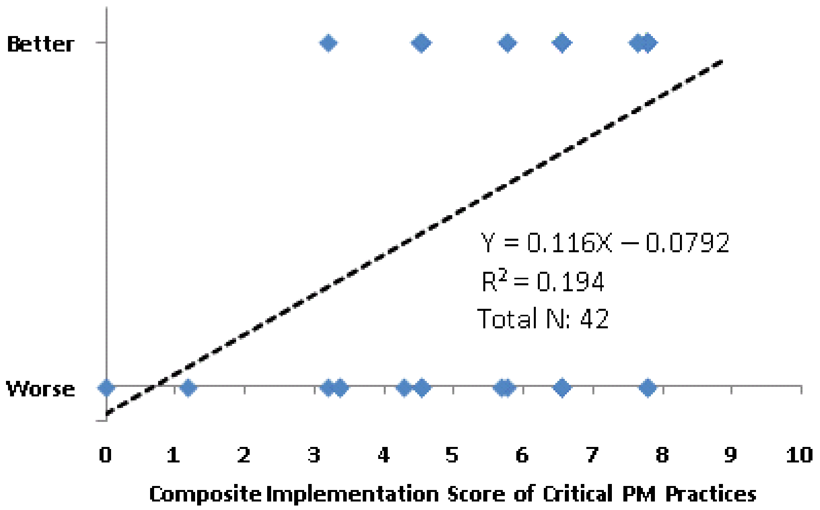
			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	10	7	58.8
		Better	7	18	72.0
	Overall Percentage				66.7

Figure 4.47: Logit Regression Analysis Results for Relationship between Number of Critical Project Management Attributes Implemented at High-Level and Business Performance

Composite Implementation Score of Critical Project Management Attributes

This section examines the combined effects of critical project management attributes on business performance by using a composite implementation score. As described in Section 3.5.8, composite implementation scores for each project were calculated based on the implementation levels of the critical project management attributes and the regression coefficients of the critical project management attributes. Figure 4.48 and 4.49 show the results analyzed from the OLS regression and the logit regression.

The OLS regression analysis results provided in Figure 4.48 shows that the composite implementation score was a significant predictor of business performance (B=0.116, P-value=0.004). The fitted regression equation ($Y = 0.116X - 0.679$) also indicated a good model fit (F=9.601, P-value =0.004) and correctly classified 69.0% of 42 contractor projects for the business performance category. The equation implies that that contractor projects could achieve better business performance ($Y>0.5$) when their composite implementation score was equal or more than 5.00.



Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
X	.116	.037	.440	3.099	.004
(Constant)	-.079	.229		-.347	.731

Model Fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.959	1	1.959	9.601	0.004
Residual	8.160	40	.204		
Total	10.119	41			

R	R Square	Adjusted R Square
0.440	.194	.173

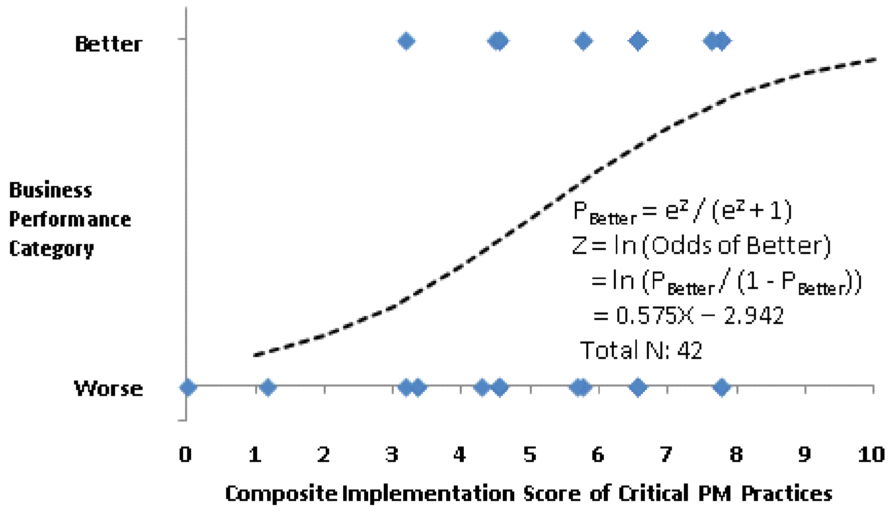
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	9	8	52.9
		Better	5	20	80.0
	Overall Percentage				69.0

Figure 4.48: Linear Regression Analysis Results for Relationship between Composite Implementation Score and Business Performance

The logit regression analysis results provided in Figure 4.49 also indicates that the composite implementation score was a highly significant predictor of business performance (B=0.575, P-value=0.000). Furthermore, a non-statistically significant result produced by the Hosmer and Lemeshow test implies that the model adequately fitted the data. With the fitted regression equation, 69.0% of 42 contractor projects were correctly classified for the business performance category. The fitted regression equation ($P_{Better} = e^{(0.575X-2.942)} / (e^{(0.575X-2.942)}+1)$) implies that the odds of better business performance were increased by a multiplicative factor of 1.777 ($=e^{(0.575)}$) for every one point increase in the composite implementation score. It also indicates that contractor projects could achieve better business performance (Y>0.5) when the composite implementation score of the critical project management attributes were 5.11 or above.

Using OLS regression and logit regression, business performance was analyzed against the implementation level of efforts committed to the critical project management attributes. The analysis utilized the two indicators: 1) the number of the critical project management attributes implemented at high-level and 2) the composite implementation score. The two indicators showed a significant relationship with business performance. In addition, the OLS and logit regression models with the two indicators showed a good model fit and classification ability. Therefore, it is implied that business performance could be explained based on the two indicators.



Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
X	.575	.225	6.517	1.000	.011	1.777
(Constant)	-2.942	1.357	4.696	1.000	.030	.053

Model Fit

Hosmer and Lemeshow Test	Chi-square	df	Sig.
	1.201	5	.945

Cox & Snell R Square	Nagelkerke R Square
.188	.254

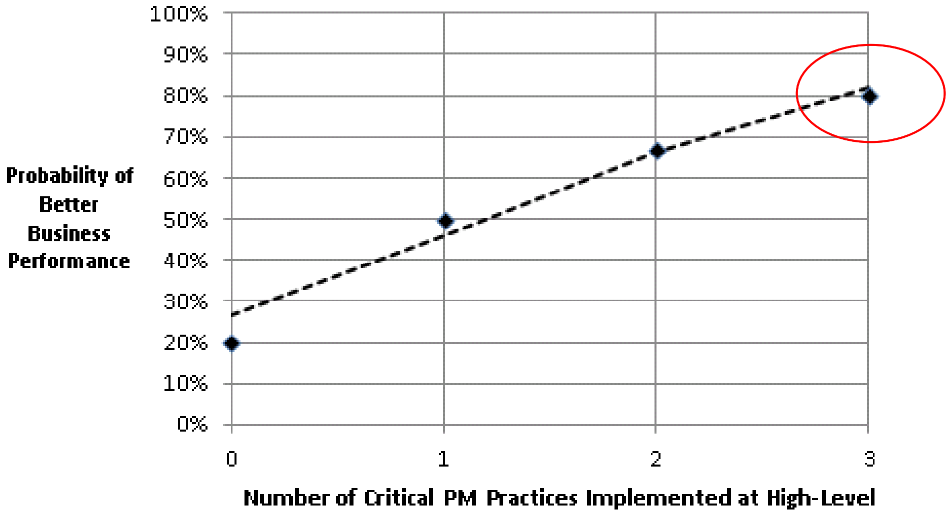
Classification Table

			Predicted		
			Performance Category		Percentage Correct
			Worse	Better	
Observed	Performance Category	Worse	9	8	52.9
		Better	5	20	80.0
	Overall Percentage				69.0

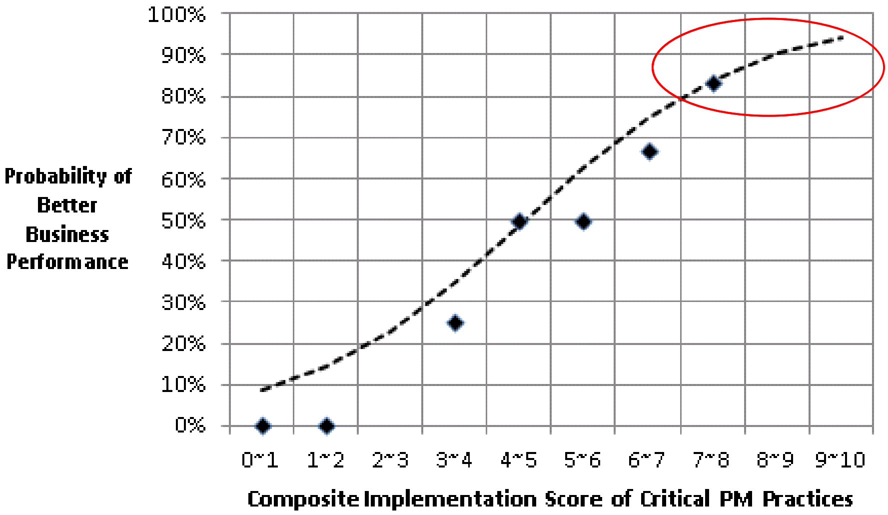
Figure 4.49: Logit Regression Analysis Results for Relationship between Composite Implementation Score and Cost Growth Performance

Figure 4.50 represents changes in the probability of better business performance in projects varied by the two indicators. Increased number of the critical project management attributes and composite implementation score shows increased probability of better business performance. Probabilities calculated based on the two indicators can be a helpful and practical reference in planning and implementing project management attributes with the goal of achieving better business performance. It can be suggested to implement six or more of the critical project management attributes at high-level and make the composite implementation score over six because projects showed a higher probability of better cost growth performance in such implementation.

To sum up, this chapter identified three critical project management attributes significantly related to business performance when they were implemented with more than a certain level of effort (Table 4.40 and Table 4.41). The regression analyses arranged the three critical project management attributes into their order of relative importance (Table 4.42). The combined effects of the three project management attributes on business performance were analyzed with the number of the critical project management attributes implemented at high-level and the composite implementation score (Figure 4.46 ~ Figure 4.50).



Number of Projects	Better	1	6	10	8
	Worse	4	6	5	2
	Total	5	12	15	10



Number of Projects	Better	0	0	0	1	4	2	8	10	0	0
	Worse	1	1	0	3	4	2	4	2	0	0
	Total	1	1	0	4	8	4	12	12	0	0

Figure 4.50: Probability of Better Business Performance by Two Indicators

4.2.6 DISCUSSION

This section discusses the implications of the analysis results described in the previous five sections. Each of the five sections identified critical project management attributes specifically for cost, schedule, safety, quality, or business performance and suggested the implementation levels for them. Table 4.43 summarizes the identified critical project management attributes and their minimum implementation levels for each of the five performance outcomes. Each column suggests a strategic guideline that can be useful in implementing project management attributes for a single performance outcome. For example, if a project only focuses on cost performance, then the analysis results under cost performance can be a reference for the selection and implementation of appropriate project management attributes.

When the goal of a project is to improve on multiple performance outcomes, it is necessary to consider the analysis results synthetically. Suppose that a project wants to achieve better performance in both cost and schedule. Since the critical project management attributes and their minimum implementation levels for the two performance outcomes are different, it is necessary to combine their analysis results to provide an implementation guideline that can be simultaneously useful for the two performance outcomes.

Table 4.43: Critical Project Management Attributes and Minimum Implementation Level

	Project Management Attribute	Cost Performance		Schedule Performance		Safety Performance		Quality Performance		Business Performance	
		Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.
1	PDRI	6.8	*	7.9	*	8.2		8.2	*	7.5	
2	FEP	5.8		6.7	*	7.0	*	5.8	*	8.1	
3	Alignment	5.0		5.3	*	5.8	*	4.2	*	4.7	*
4	Partnering	6.4		7.3		5.1	*	0.1		5.1	
5	Team Building	-		5.8		7.4	*	7.4		7.4	
6	Change Management	7.7	*	8.5	*	7.7	*	8.6		7.7	*
7	Constructability	3.8	*	7.4	*	5.3	*	6.3		3.0	
8	Project Risk Analysis	1.1	*	7.7	*	1.3		-		7.3	
9	Planning for Startup	6.1	*	6.1		4.9		6.5	*	-	
10	Zero Accident Technique	5.6		8.6		7.2		7.1		8.5	
11	Timely Engineering	7.6		7.2		4.3		5.8	*	4.3	*
12	Accurate Engineering	5.8	*	5.8		4.3		5.8		2.9	
13	Alliance	5.8		-		-		-		-	
14	Budget Accuracy	6.1	*	8.1	*	-		8.1		4.1	
15	Fast Track (Yes or No)	Yes		No		No		Yes		No	
16	Modularization	-		-		1.1		1.1		1.1	

Table 4.44 shows an example of how the implementation level for both cost and schedule performance outcomes is recommended. Between the implementation levels for the two performance outcomes, the higher implementation level can be chosen from a conservative point of view. For instance, the implementation level of project definition rating index for cost performance is 6.8, while the implementation level of project definition rating index for schedule performance outcome is 7.9. In this case, 7.9 is the minimum implementation level for combined goal of cost and schedule performance improvement. The last column shows the conservatively minimum implementation levels for each project management attribute.

Table 4.44: Example of Implication of Table 4.43

Project Management Attribute		Cost Performance		Schedule Performance		Cost & Schedule Performance	
		Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.	Minimum Implementation Level	Sig.
1	Project Definition Rating Index	6.8	*	7.9	*	7.9	B
2	FEP	5.8		6.7	*	6.7	S
3	Alignment	5.0		5.3	*	5.3	S
4	Partnering	6.4		7.3		7.3	
5	Team Building	-		5.8		5.8	
6	Change Management	7.7	*	8.5	*	8.5	B
7	Constructability	3.8	*	7.4	*	7.4	B
8	Project Risk Analysis	1.1	*	7.7	*	7.7	B
9	Planning for Startup	6.1	*	6.1		6.1	C
10	Zero Accident Technique	5.6		8.6		8.6	
11	Timely Engineering	7.6		7.2		7.6	
12	Accurate Engineering	5.8	*	5.8		5.8	C
13	Alliance	5.8		-		5.8	
14	Budget Accuracy	6.1	*	8.1	*	8.1	B
15	Fast Track (Yes or No)						
16	Modularization	-		-			

B: Both, C: Cost, and S: Schedule

To achieve better cost and schedule performance at the same time, the most appropriate strategy might be to implement all of the nine project management attributes related to either cost or schedule performance outcome. It may be preferable to focus on implementing the five project management attributes shown to have a significant relationship with both cost and schedule performance outcomes (project definition rating index, change management, constructability, project risk assessment, and budget accuracy). However, it is difficult to assert that these five project management attributes are more important than the other three attributes solely because of their relationship with both performance outcomes. For example, although the planning for startup attribute is a critical project management attribute for cost performance, but not for schedule performance, it is the second most critical attribute for good cost performance as shown in Table 4.26. Therefore, it would be best to implement all of the nine critical project management attributes to the minimum implementation level.

In the same way described in the previous example, the most appropriate project management implementation guideline can be developed for each combination of project performance outcomes. Since projects have different performance goals, a project management implementation guideline tailored to a project's performance goal should be most helpful. Table 4.43 is expected to provide such a project management implementation guideline for owner projects.

CHAPTER 5: CONCLUSIONS

This chapter summarizes this study and draws important conclusions. It provides a summary of the study, discusses implications for action, documents research contributions, and provides recommendations for further research.

5.1 SUMMARY OF THE STUDY

The primary goal of this study was to provide effective implementation guidelines of project management attributes by analyzing the relationships between project management attributes and project performance outcomes. The literature review in Chapter 2 provided a foundation for this research. The research methodology was described in Chapter 3, including the step-by-step analysis approaches utilized to examine the research questions. The analysis results were presented in Chapter 4. Based on the results, project management attribute guidelines were provided for each of cost, schedule, safety, quality and business performance. The implementation guidelines are presented in the Recommendations for Action section.

The research questions were examined by the statistical analysis methods and their conclusions are summarized as follows:

1) What is the level of effort required for the implementation of a given project management attribute for better performance?

For a specific performance outcome, the minimum implementation level for each project management attribute was identified by the contingency table analysis. Based on the identified implementation level, projects were divided into two groups: implemented at high-level or implemented at low-level. Then, the two groups were tested using the chi-square and the Fisher's exact test to see whether there is a significant difference in project performance between them. The minimum implementation levels for better performance varied according to each project management attribute, project performance outcome, and owner or contractor projects (Appendix C).

2) Which project management attributes are significantly related to better project performance outcomes?

Whether a project management attribute is significantly related to a project performance outcome was examined by three univariate regression methods. When all three methods showed a significant relationship, a project management attribute was considered to be a critical project management attribute for a particular project performance outcome. Different critical project management attributes were identified for each project performance outcome, grouped by owner and contractor projects (Table 4.21 and Table

4.43). For owner projects, 10 to 14 project management attributes were regarded as critical project management attributes for the five project performance outcomes among 19 project management attributes examined. It is notable that FEP, alignment, and planning for startup attributes were identified as critical project management attributes for all five performance outcomes, which suggests that these three attributes need to be implemented at a high-level for better overall project performance. For contractor projects, on the other hand, three to seven project management attributes were found to be critical among the 16 project management attributes analyzed. Alignment and change management were critical project management attributes for four of the performance outcomes.

3) Which critical project management attributes are more influential on improved project performance?

The relative importance of the identified critical project management attributes was derived from three multivariate regression analyses. The average rank of the three analysis methods was used to determine their relative importance for each of the five project performance outcomes, as shown in Tables 4.4, 4.8, 4.12, 4.16 and 4.20 for owner projects, and in Tables 4.26, 4.30, 4.34, 4.38, and 4.42 for contractor projects. It was identified that there were differences in the possible effect sizes of the critical attributes for each project performance outcome.

4) What are the combined effects of critical project management attributes on project performance outcomes?

The combined effects of critical project management attributes were analyzed based on two indicators: the number of the critical project management attributes implemented at a high-level and the composite implementation score of the critical project management attributes. The suitability for explaining the effects by using the two indicators was examined and supported by regression analyses. The effects were quantified in terms of probability of better performance. An increase in the two indicators was confirmed to be related to higher probability for better performance of all five performance outcomes. The effects quantified by the number of the critical project management attributes can be used as a reasonable reference before an explicit implementation plan is established, while the effects quantified by the composite implementation score can be useful to develop and/or evaluate a specific implementation plan.

5.2 RECOMMENDATIONS FOR ACTION

Based on the finding of this study, this section recommends actions for professionals to employ to ensure that the implementation of project management attributes lead to achieve better project performance. Depending on the objectives of a project, the implementation guidelines shown in Table 5.1 ~ 5.10 should be followed. The guidelines include the most effective way to implement project management attributes to increase the probability of desirable project performance outcomes. Each Table shows the critical project management attributes for a project performance outcome. Key information is provided including the relative importance of each attribute, the minimum implementation score, necessary actions, and accumulated probabilities for better performance.

If it is discovered that an implementation plan does not cover the action items suggested by the implementation guidelines, it is important to revise and update the plan so that better project performance can be achieved. Implementing all of the critical project management attributes by following the required actions is expected to maximize the probability of better project performance. In instances where implementation resources are limited, however, the most effective way to implement the project management attributes for a project performance outcome would be to select attributes in order of their relative importance, because the most influential attribute is ranked first.

When a project management attribute requires multiple activities, it is possible to consider different scenarios to satisfy the minimum implementation level. The required actions in Tables 5.1 ~ 5.10 were derived based on the assumption that the level of difficulty in implementing each action is equal. As a result, the activities whose relative weight (Appendix B) was largest was preferentially chosen. However, in cases where the equal assumption is not applied for each action, it is possible to establish different scenarios which are the most appropriate to a given project environment by adjusting the implementation levels for each action to meet the minimum implementation level.

Specific implementation reference for each of project performance outcomes are represented by the following 10 Tables:

Table 5.1: Cost Performance for Owner Projects

Table 5.2: Schedule Performance for Owner Projects

Table 5.3: Safety Performance for Owner Projects

Table 5.4: Quality Performance for Owner Projects

Table 5.5: Business Performance for Owner Projects

Table 5.6: Cost Performance for Contractor Projects

Table 5.7: Schedule Performance for Contractor Projects

Table 5.8: Safety Performance for Contractor Projects

Table 5.9: Quality Performance for Contractor Projects

Table 5.10: Business Performance for Contractor Projects

Table 5.1: Cost Performance for Owner Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Project Definition Rating Index	1	8.7		Complete scope definition to reach at least 190 PDRI score	40.0%
Timely Engineering	2	4.3		Complete more than half of engineering deliverables in time	71.1%
Front End Planning	3	7.7	High	Organize a skilled and experienced FEP team	90.1%
			High	Organize an authoritative and representative FEP team	
			High	Document the FEP activities	
			High	Communicate the owner's objectives, needs and expectations to the FEP team	
			High	Align the FEP team with the owner's objectives, needs and expectations	
			High	Evaluate the technology during FEP	
			High	Analyze the risk of project alternatives during FEP	
			High	Identify and clarify risk mitigation strategies during FEP	
			High	Use a tool to measure the level of definition	
			High	Complete the final scope definition	
			Middle	Align the budget and schedule with the final scope definition	
Partnering	4	6.3	High	Obtain your company's commitment to partnering	97.0%
			High	Specify the terms of the contract to support/facilitate the partnering relationship	
			High	Develop partnering implementation plan jointly	
			High	Assign a partnering champion or sponsor who is responsible for supporting the partnering relationship	
			High	Conduct an initial kick off partnering workshop	
			High	Establish an open environment so that team members can feel free to offer suggestions	
			High	Develop the partnering relationship to facilitate/promote innovation	
			High	Make a collaborate decision on the partnering	
			High	Make sure that an evaluation process should be useful for implementing improvements to the partnering process	
			High	Develop the partnering relationship that includes a shared vision, shared culture, and trust	
			Low-Middle	Include the following elements in the partnering agreement: 1) a mission statement for the partnering relationship, 2) operating principles, 3) specification of expectations of the relationship, 4) goals and objectives for the relationship, 5) measures of success by which the services to be provided are judged, 6) sharing of business plans and other key business information, and 7) incentive provisions to reinforce partnering	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.1: Cost Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Alignment	5	5.7	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	98.7%
			High	Define the project goals and objectives during FEP	
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			High	Use planning tools to promote alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	
Change Management	6	8.1	High	Establish a formal (documented in writing) change management process	99.4%
			High	Specify the change management process in the contract	
			High	Make sure that key project personnel (both owners and contractors) understand the change management process	
			High	Manage changes proactively (timely, hands-on, and aggressive management)	
			High	Go through a formal change justification procedure for major changes (i.e., those that exceeded a specified project threshold)	
			High	Communicate change information to key project participants	
			High	Identify and evaluate areas susceptible to change during review of the project design phase	
			High	Negotiate and authorize change orders in a timely manner	
			Middle	Manage changes proactively (timely, hands-on, and aggressive management) during detail engineering	
Accurate Engineering	7	7.2		Complete more than half of engineering deliverables accurately	99.7%
Percent Design Completion prior to construction	8	3.2		Complete at least 32% of design prior to construction	99.8%

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.1: Cost Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Planning for Startup	9	5.6	High	Define the startup objectives	99.8%
			High	Communicate startup objectives to the relevant project team members	
			High	Allocate adequate resources to planning for startup	
			High	Develop a formal startup execution plan	
			High	Implement a formal startup execution plan	
			High	Identify major startup systems and startup sequences during front end engineering	
			High	Drive the startup schedule by the startup sequence	
			High	Have formal trainings for operator/maintenance	
			High	Develop startup procedures by the intensively involved startup team	
			Low	Identify the startup team's roles and responsibilities and communicate them to all project stakeholders	
			Low	Communicate the startup team's roles and responsibilities to all project stakeholders	
			Low	Develop the system turnover plan	
Percent Design Completion at AFE	10	4.1		Complete at least 41% of design at AFE	99.9%
Alliance with Contractors	11	7.2		Establish more than a moderate alliance relationship with the primary contractor for better communication, cooperation, and trust, as well as more risk sharing	99.9%
Project Delivery and Contract Strategy	12	8.3	High	Consider alternative project delivery methods	99.9%
			High	Evaluate the strengths and weaknesses of alternative project delivery methods during the business planning stage	
			High	Consider alternative contract types	
			High	Evaluate the strengths and weaknesses of alternative contract types for the primary contractor during the business planning stage	
			High	Look back on other projects to make sure that the selected delivery method is the most optimal	
			High	Consider alternative contract types for the primary contractor	
			High	Rank and prioritize different project delivery methods in terms of suitability	
			High	Rank and prioritize different contract types in terms of suitability	
			High	Use a tool for assisting with the determination of the project delivery method and contract type	
			Low-Middle	Review the business objectives and rank the relative importance of these objectives during the business planning stage	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.2: Schedule Performance for Owner Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Accurate Engineering	1	5.8		Complete more than half of engineering deliverables accurately	1.1%
			High	Define the startup objectives	
			High	Communicate startup objectives to the relevant project team members	
			High	Allocate adequate resources to planning for startup	
			High	Develop a formal startup execution plan	
			High	Implement a formal startup execution plan	
			High	Identify major startup systems and startup sequences during front end engineering	
Planning for Startup	2	7.0	High	Drive the startup schedule by the startup sequence	3.7%
			High	Have formal trainings for operator/maintenance	
			High	Develop startup procedures by the intensively involved startup team	
			Low	Identify the startup team's roles and responsibilities and communicate them to all project stakeholders	
			Low	Communicate the startup team's roles and responsibilities to all project stakeholders	
			Low	Develop the system turnover plan	
Percent Design Completion prior to construction	3	3.2		Complete at least 32% of design prior to construction	10.0%
			High	Make sure that all of the necessary, relevant project team members involved in the risk assessment process Implement the risk mitigation plan	
				Update the risk mitigation plan	
Project Risk Assessment	4	4.4	High	Implement the risk mitigation plan	21.0%
			Middle-High	Conduct the first formal risk assessment at the early project phase (feasibility study)	
			Low-Middle	Update the risk assessment	
			Low	Document the risk assessment process	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.2: Schedule Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Change Management	5	6.2	High	Establish a formal (documented in writing) change management process	36.3%
			High	Specify the change management process in the contract	
			High	Make sure that key project personnel (both owners and contractors) understand the change management process	
			High	Manage changes proactively (timely, hands-on, and aggressive management)	
			High	Negotiate and authorize change orders in a timely manner	
			Middle-High	Go through a formal change justification procedure for major changes (i.e., those that exceeded a specified project threshold)	
			Low-Middle	Communicate change information to key project participants	
			Low-Middle	Identify and evaluate areas susceptible to change during review of the project design phase	
Partnering	6	6.0	High	Specify the terms of the contract to support/facilitate the partnering relationship	53.7%
			High	Develop partnering implementation plan jointly	
			High	Assign a partnering champion or sponsor who is responsible for supporting the partnering relationship	
			High	Conduct an initial kick off partnering workshop	
			High	Establish an open environment so that team members can feel free to offer suggestions	
			High	Develop the partnering relationship to facilitate/promote innovation	
			High	Make a collaborate decision on the partnering	
			High	Make sure that an evaluation process should be useful for implementing improvements to the partnering process	
			High	Develop the partnering relationship that includes a shared vision, shared culture, and trust	
			Low-Middle	Obtain your company's commitment to partnering	
			Low-Middle	Include the following elements in the partnering agreement: 1) a mission statement for the partnering relationship, 2) operating principles, 3) specification of expectations of the relationship, 4) goals and objectives for the relationship, 5) measures of success by which the services to be provided are judged, 6) sharing of business plans and other key business information, and 7) incentive provisions to reinforce partnering	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.2: Schedule Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Team Building	7	6.7	High	Commit your company's resources to formal team building	68.9%
			High	Run a formal team building program	
			High	Make sure that the relevant and representative stakeholders participate in the team building workshop(s)	
			High	Hold a sufficient number of follow up team building meetings to reinforce team building concepts and integrate new team members	
			Low-Middle	Hold one or more retreat type workshops where shared goals are developed and essential decision making and dispute resolution procedures are worked out	
Project Delivery and Contract Strategy	8	6.2	High	Consider alternative project delivery methods	80.5%
			High	Evaluate the strengths and weaknesses of alternative project delivery methods during the business planning stage	
			High	Consider alternative contract types	
			High	Evaluate the strengths and weaknesses of alternative contract types for the primary contractor during the business planning stage	
			High	Look back on other projects to make sure that the selected delivery method is the most optimal	
			High	Consider alternative contract types for the primary contractor	
			Low	Review the business objectives and rank the relative importance of these objectives during the business planning stage	
Alliance with Contractors	9	5.8		Establish a moderate alliance relationship with the primary contractor at least moderately for better communication, cooperation, and trust, as well as more risk sharing	82.6%
Timely Engineering	10	7.2		Complete more than half of engineering deliverables in time	83.8%

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.2: Schedule Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Alignment	11	6.0	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	83.8%
			High	Define the project goals and objectives during FEP	
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			High	Use planning tools to promote alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)	
			Low-Middle	Develop the FEP team culture to foster trust, honesty and open communication	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	
Front End Planning	12	7.5	High	Organize a skilled and experienced FEP team	83.8%
			High	Organize an authoritative and representative FEP team	
			High	Document the FEP activities	
			High	Communicate the owner's objectives, needs and expectations to the FEP team	
			High	Align the FEP team with the owner's objectives, needs and expectations	
			High	Evaluate the technology during FEP	
			High	Analyze the risk of project alternatives during FEP	
			High	Identify and clarify risk mitigation strategies during FEP	
			High	Use a tool to measure the level of definition	
			High	Align the budget and schedule with the final scope definition	
			Middle	Complete the final scope definition	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.3: Safety Performance for Owner Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Front End Planning	1	9.1	High	Organize a skilled and experienced FEP team	54.3%
			High	Organize an authoritative and representative FEP team	
			High	Define the roles and responsibilities of the FEP team members	
			High	Develop an effective communication environment among the FEP team members	
			High	Document the FEP activities	
			High	Communicate the owner's objectives, needs and expectations to the FEP team	
			High	Align the FEP team with the owner's objectives, needs and expectations	
			High	Evaluate the technology during FEP	
			High	Analyze the risk of project alternatives during FEP	
			High	Identify and clarify risk mitigation strategies during FEP	
			High	Use a tool to measure the level of definition	
			High	Complete the final scope definition	
			High	Align the budget and schedule with the final scope definition	
			Middle-High	Address necessary regulatory permits during FEP	
			Low	Evaluate alternate site locations	
Project Risk Assessment	2	7.4	High	Conduct the first formal risk assessment at the early project phase (feasibility study)	88.2%
			High	Update the risk assessment	
			High	Develop a risk mitigation plan	
			High	Update the risk mitigation plan	
				Implement the risk mitigation plan	
			High	Conduct formal risk assessment(s)	
			High	Use an outside facilitator to assist with risk assessment	
			High	Document the risk assessment process	
			Middle	Add the mitigation costs and contingency to the authorized project budget as a result of the risk assessment process	
			Low	Make sure that all of the necessary, relevant project team members involved in the risk assessment process Implement the risk mitigation plan	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.3: Safety Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Constructability	3	7.8	High	Assign a full time constructability coordinator to play a major constructability role	97.4%
			High	Apply constructability concepts and principles systematically at the earliest project phase (Early FEP)	
			High	Assign appropriate, knowledgeable construction personnel to effectively interface with appropriate design personnel (design personnel with authority over design issues)	
			High	Integrate the constructability plan into the project execution plan	
			High	Provide a full funding for constructability	
			High	Make sure that the engineering deliverables can reflect the recommendations for constructability from construction personnel	
			High	Establish a stand-alone corporate program that is generally on the same level as quality or safety	
			High	Develop a a formal documented constructability plan	
			Middle-High	Communicate constructability principles	
			Low-Middle	Evaluate, update and improve construability efforts periodically	
Project Delivery and Contract Strategy	4	8.8	High	Consider alternative project delivery methods	99.2%
			High	Evaluate the strengths and weaknesses of alternative project delivery methods during the business planning stage	
			High	Consider alternative contract types	
			High	Evaluate the strengths and weaknesses of alternative contract types for the primary contractor during the business planning stage	
			High	Look back on other projects to make sure that the selected delivery method is the most optimal	
			High	Review the business objectives and rank the relative importance of these objectives during the business planning stage	
			High	Consider alternative contract types for the primary contractor	
			High	Rank and prioritize different project delivery methods in terms of suitability	
			High	Rank and prioritize different contract types in terms of suitability	
			High	Use a tool for assisting with the determination of the project delivery method and contract type	
Timely Engineering	5	8.6		Complete most of engineering deliverables in time	99.8%
Modularization	6	2.1		Apply modularization at least 21% of the project	99.9%

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.3: Safety Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Zero Accident Technique	7	6.4	High	Develop a written site specific safety plan	100%
			High	Assign a full time site safety supervisor	
			High	Conduct the job-specific safety orientation for new contractor and subcontractor employees	
			High	Hold safety toolbox meetings more than 2 times per day	
			High	Perform safety audits by corporate safety personnel on a weekly basis	
			High	Investigate every near-misses formally (i.e., written documentation)	
			High	Identify safety risks systematically in the pre-construction phases	
Partnering	8	7.0	High	Specify the terms of the contract to support/facilitate the partnering relationship	100%
			High	Develop partnering implementation plan jointly	
			High	Assign a partnering champion or sponsor who is responsible for supporting the partnering relationship	
			High	Establish an open environment so that team members can feel free to offer suggestions	
			High	Develop the partnering relationship to facilitate/promote innovation	
			High	Make a collaborate decision on the partnering	
			High	Make sure that an evaluation process should be useful for implementing improvements to the partnering process	
			High	Develop the partnering relationship that includes a shared vision, shared culture, and trust	
			High	Obtain your company's commitment to partnering	
			High	Have a partnering agreement on this project with the primary contractor	
			High	Include the following elements in the partnering agreement: 1) a mission statement for the partnering relationship, 2) operating principles, 3) specification of expectations of the relationship, 4) goals and objectives for the relationship, 5) measures of success by which the services to be provided are judged, 6) sharing of business plans and other key business information, and 7) incentive provisions to reinforce partnering	
			High	Conduct an initial kick off partnering workshop	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.3: Safety Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Planning for Startup	9	6.9	High	Define the startup objectives	100%
			High	Communicate startup objectives to the relevant project team members	
			High	Allocate adequate resources to planning for startup	
			High	Develop a formal startup execution plan	
			High	Implement a formal startup execution plan	
			High	Identify major startup systems and startup sequences during front end engineering	
			High	Drive the startup schedule by the startup sequence	
			High	Have formal trainings for operator/maintenance	
			High	Develop startup procedures by the intensively involved startup team	
			High	Identify the startup team's roles and responsibilities and communicate them to all project stakeholders	
			High	Use tools or checklists to develop the startup plan and evaluate the extent of startup planning	
			Middle-High	Communicate the startup team's roles and responsibilities to all project stakeholders	
			Middle-High	Develop the system turnover plan	
Alignment	10	7.2	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	100%
			High	Define the project goals and objectives during FEP	
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			High	Use planning tools to promote alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)	
			High	Have team meetings for gaining alignment on project objectives	
			High	Make sure that communication in the FEP process becomes two-way communication	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.4: Quality Performance for Owner Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Alignment	1	8.6	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	4.4%
			High	Define the project goals and objectives during FEP	
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			High	Use planning tools to promote alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)	
			Low-Middle	Develop the FEP team culture to foster trust, honesty and open communication	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	
Constructability	2	2.1	High	Assign a full time constructability coordinator to play a major constructability role	28.9%
			High	Apply constructability concepts and principles systematically at the earliest project phase (Early FEP)	
			High	Assign appropriate, knowledgeable construction personnel to effectively interface with appropriate design personnel (design personnel with authority over design issues)	
			High	Integrate the constructability plan into the project execution plan	
			High	Provide a full funding for constructability	
			High	Make sure that the engineering deliverables can reflect the recommendations for constructability from construction personnel	
			High	Establish a stand-alone corporate program that is generally on the same level as quality or safety	
			High	Develop a formal documented constructability plan	
			Middle-High	Communicate constructability principles	
			Low-Middle	Evaluate, update and improve construability efforts periodically	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.4: Quality Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Front End Planning	3	9.1	High	Organize a skilled and experienced FEP team	75.5%
			High	Organize an authoritative and representative FEP team	
			High	Document the FEP activities	
			High	Communicate the owner's objectives, needs and expectations to the FEP team	
			High	Align the FEP team with the owner's objectives, needs and expectations	
			High	Evaluate the technology during FEP	
			High	Analyze the risk of project alternatives during FEP	
			High	Identify and clarify risk mitigation strategies during FEP	
			High	Use a tool to measure the level of definition	
			High	Align the budget and schedule with the final scope definition	
			Middle	Complete the final scope definition	
Project Risk Assessment	4	8.8	High	Make sure that all of the necessary, relevant project team members involved in the risk assessment process Implement the risk mitigation plan	94.4%
				Update the risk mitigation plan	
			High	Implement the risk mitigation plan	
			Middle-High	Conduct the first formal risk assessment at the early project phase (feasibility study)	
			Low-Middle	Update the risk assessment	
			Low	Document the risk assessment process	
Project Definition Rating Index	5	7.9		Complete scope definition to reach at least 266 PDRI score	98.5%
Modularization	5	2.1		Apply modularization at least 21% of the project	99.6%
Alliance with Contractors	7	8.6		Establish a very active alliance relationship with the primary contractor for better communication, cooperation, and trust, as well as more risk sharing	99.9%

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.4: Quality Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Change Management	8	6.5	High	Establish a formal (documented in writing) change management process	100%
			High	Specify the change management process in the contract	
			High	Make sure that key project personnel (both owners and contractors) understand the change management process	
			High	Manage changes proactively (timely, hands-on, and aggressive management)	
			High	Negotiate and authorize change orders in a timely manner	
			Middle-High	Go through a formal change justification procedure for major changes (i.e., those that exceeded a specified project threshold)	
			Low-Middle	Communicate change information to key project participants	
			Low-Middle	Identify and evaluate areas susceptible to change during review of the project design phase	
Percent Design Completion prior to construction	9	3.2		Complete at least 32% of design prior to construction	100%
Budget Accuracy	10	8.1		Make sure that the accuracy of the budget at the time of authorization should be within from -15% to +20%.	100%
Planning for Startup	11	9.0	High	Define the startup objectives	100%
			High	Communicate startup objectives to the relevant project team members	
			High	Allocate adequate resources to planning for startup	
			High	Develop a formal startup execution plan	
			High	Implement a formal startup execution plan	
			High	Identify major startup systems and startup sequences during front end engineering	
			High	Drive the startup schedule by the startup sequence	
			High	Have formal trainings for operator/maintenance	
			High	Develop startup procedures by the intensively involved startup team	
			Low	Identify the startup team's roles and responsibilities and communicate them to all project stakeholders	
			Low	Communicate the startup team's roles and responsibilities to all project stakeholders	
			Low	Develop the system turnover plan	
Project Delivery and Contract Strategy	12	9.1	High	Consider alternative project delivery methods	100%
			High	Evaluate the strengths and weaknesses of alternative project delivery methods during the business planning stage	
			High	Consider alternative contract types	
			High	Evaluate the strengths and weaknesses of alternative contract types for the primary contractor during the business planning stage	
			High	Look back on other projects to make sure that the selected delivery method is the most optimal	
			High	Consider alternative contract types for the primary contractor	
			Low	Review the business objectives and rank the relative importance of these objectives during the business planning stage	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.5: Business Performance for Owner Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Alignment	1	7.6	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	3.8%
			High	Define the project goals and objectives during FEP	
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			High	Use planning tools to promote alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)	
			Low-Middle	Develop the FEP team culture to foster trust, honesty and open communication	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	
Percent Design Completion at AFE	2	5.1		Complete at least 51% of design prior to construction	13.6%
Project Definition Rating Index	3	8.3		Complete scope definition to reach at least 229 PDRI score	36.7%
Partnering	4	7.3	High	Specify the terms of the contract to support/facilitate the partnering relationship	66.9%
			High	Develop partnering implementation plan jointly	
			High	Assign a partnering champion or sponsor who is responsible for supporting the partnering relationship	
			High	Establish an open environment so that team members can feel free to offer suggestions	
			High	Develop the partnering relationship to facilitate/promote innovation	
			High	Make a collaborate decision on the partnering	
			High	Make sure that an evaluation process should be useful for implementing improvements to the partnering process	
			High	Develop the partnering relationship that includes a shared vision, shared culture, and trust	
			High	Obtain your company's commitment to partnering	
			High	Have a partnering agreement on this project with the primary contractor	
			High	Include the following elements in the partnering agreement: 1) a mission statement for the partnering relationship, 2) operating principles, 3) specification of expectations of the relationship, 4) goals and objectives for the relationship, 5) measures of success by which the services to be provided are judged, 6) sharing of business plans and other key business information, and 7) incentive provisions to reinforce partnering	
			High	Conduct an initial kick off partnering workshop	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.5: Business Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Project Risk Assessment	5	1.3	High	Make sure that all of the necessary, relevant project team members involved in the risk assessment process Implement the risk mitigation plan	87.8%
				Update the risk mitigation plan	
			High	Implement the risk mitigation plan	
			Middle-High	Conduct the first formal risk assessment at the early project phase (feasibility study)	
			Low-Middle	Update the risk assessment	
			Low	Document the risk assessment process	
Timely Engineering	6	4.3		Complete more than half of engineering deliverables in time	95.9%
Zero Accident Technique	7	8.4	High	Develop a written site specific safety plan	98.5%
			High	Assign a full time site safety supervisor	
			High	Conduct the job-specific safety orientation for new contractor and subcontractor employees	
			High	Hold safety toolbox meetings more than 2 times per day	
			High	Perform safety audits by corporate safety personnel on a weekly basis	
			High	Investigate every near-misses formally (i.e., written documentation)	
			High	Identify safety risks systematically in the pre-construction phases	
Front End Planning	8	8.1	High	Organize a skilled and experienced FEP team	99.4%
			High	Organize an authoritative and representative FEP team	
			High	Define the roles and responsibilities of the FEP team members	
			High	Develop an effective communication environment among the FEP team members	
			High	Document the FEP activities	
			High	Communicate the owner's objectives, needs and expectations to the FEP team	
			High	Align the FEP team with the owner's objectives, needs and expectations	
			High	Evaluate the technology during FEP	
			High	Analyze the risk of project alternatives during FEP	
			High	Identify and clarify risk mitigation strategies during FEP	
			High	Use a tool to measure the level of definition	
			High	Complete the final scope definition	
			High	Align the budget and schedule with the final scope definition	
			Middle-High	Address necessary regulatory permits during FEP	
			Low	Evaluate alternate site locations	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.5: Business Performance for Owner Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Change Management	9	6.1	High	Establish a formal (documented in writing) change management process	99.7%
			High	Specify the change management process in the contract	
			High	Make sure that key project personnel (both owners and contractors) understand the change management process	
			High	Manage changes proactively (timely, hands-on, and aggressive management)	
			High	Negotiate and authorize change orders in a timely manner	
			Middle-High	Go through a formal change justification procedure for major changes (i.e., those that exceeded a specified project threshold)	
			Low-Middle	Communicate change information to key project participants	
			Low-Middle	Identify and evaluate areas susceptible to change during review of the project design phase	
Budget Accuracy	9	8.1		Make sure that the accuracy of the budget at the time of authorization should be within from -15% to +20%.	99.9%
Planning for Startup	11	8.3	High	Define the startup objectives	99.9%
			High	Communicate startup objectives to the relevant project team members	
			High	Allocate adequate resources to planning for startup	
			High	Develop a formal startup execution plan	
			High	Implement a formal startup execution plan	
			High	Identify major startup systems and startup sequences during front end engineering	
			High	Drive the startup schedule by the startup sequence	
			High	Have formal trainings for operator/maintenance	
			High	Develop startup procedures by the intensively involved startup team	
			Low	Identify the startup team's roles and responsibilities and communicate them to all project stakeholders	
			Low	Communicate the startup team's roles and responsibilities to all project stakeholders	
			Low	Develop the system turnover plan	
Alliance with Contractors	12	8.6		Establish a very active alliance relationship with the primary contractor for better communication, cooperation, and trust, as well as more risk sharing	99.9%
Accurate Engineering	13	7.2		Complete more than half of engineering deliverables accurately	99.9%
Percent Design Completion prior to construction	14	3.2		Complete at least 32% of design prior to construction	99.9%

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.6: Cost Performance for Contractor Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Constructability	1	3.8	High	Assign appropriate, knowledgeable construction personnel to effectively interface with appropriate design personnel (design personnel with authority over design issues)	0.6%
			Middle-High	Assign a full time constructability coordinator to play a major constructability role	
			Middle-High	Apply constructability concepts and principles systematically at the earliest project phase (Early FEP)	
			Middle-High	Integrate the constructability plan into the project execution plan	
			Middle-High	Make sure that the engineering deliverables can reflect the recommendations for constructability from construction personnel	
			Low-Middle	Provide a full funding for constructability	
			Low	Communicate constructability principles	
			Low	Identify and remove barriers to constructability	
Planning for Startup	2	6.1	High	Define the startup objectives	3.8%
			High	Communicate startup objectives to the relevant project team members	
			High	Allocate adequate resources to planning for startup	
			High	Develop a formal startup execution plan	
			High	Implement a formal startup execution plan	
			High	Identify major startup systems and startup sequences during front end engineering	
			High	Drive the startup schedule by the startup sequence	
			High	Have formal trainings for operator/maintenance	
			High	Develop startup procedures by the intensively involved startup team	
			High	Use tools or checklists to develop the startup plan and evaluate the extent of startup planning	
			Low-Middle	Communicate the startup team's roles and responsibilities to all project stakeholders	
			Low	Develop the system turnover plan	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.6: Cost Performance for Contractor Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Project Definition Rating Index	3	6.8		Complete scope definition to reach at least 229 PDRI score	17.7%
Project Risk Assessment	4	1.1	High	Implement the risk mitigation plan	48.8%
			Low-Middle	Update the risk assessment	
			Low	Document the risk assessment process	
			Low	Update the risk mitigation plan	
Budget Accuracy	5	6.1		Make sure that the accuracy of the budget at the time of authorization should be within from -20% to +30%.	78.7%
Accurate Engineering	6	5.8		Complete more than half of engineering deliverables accurately	89.3%
Change Management	7	7.7	High	Establish a formal (documented in writing) change management process	94.4%
			High	Specify the change management process in the contract	
			High	Make sure that key project personnel (both owners and contractors) understand the change management process	
			High	Manage changes proactively (timely, hands-on, and aggressive management)	
			High	Negotiate and authorize change orders in a timely manner	
			High	Manage changes proactively (timely, hands-on, and aggressive management) during construction/ startup	
			High	Communicate change information to key project participants	
			Middle-High	Go through a formal change justification procedure for major changes (i.e., those that exceeded a specified project threshold)	
			Middle-High	Identify and evaluate areas susceptible to change during review of the project design phase	
			Low	Make sure that the owner authorizes before implementation of major changes	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.7: Schedule Performance for Contractor Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Constructability	1	7.4	High	Assign a full time constructability coordinator to play a major constructability role	58.9%
			High	Apply constructability concepts and principles systematically at the earliest project phase (Early FEP)	
			High	Assign appropriate, knowledgeable construction personnel to effectively interface with appropriate design personnel (design personnel with authority over design issues)	
			High	Integrate the constructability plan into the project execution plan	
			High	Provide a full funding for constructability	
			High	Make sure that the engineering deliverables can reflect the recommendations for constructability from construction personnel	
			High	Establish a stand-alone corporate program that is generally on the same level as quality or safety	
			High	Develop a formal documented constructability plan	
			Low-Middle	Evaluate, update and improve construability efforts periodically	
Project Risk Assessment	1	7.7	High	Conduct the first formal risk assessment at the early project phase (feasibility study)	94.7%
			High	Update the risk assessment	
			High	Make sure that all of the necessary, relevant project team members involved in the risk assessment process Implement the risk mitigation plan	
			High	Develop a risk mitigation plan	
			High	Update the risk mitigation plan	
			High	Implement the risk mitigation plan	
			High	Conduct formal risk assessment(s)	
			High	Use an outside facilitator to assist with risk assessment	
			High	Add the schedule impacts of mitigation to the baseline project schedule as a result of the risk assessment process	
			Middle-High	Document the risk assessment process	
			Middle	Add the mitigation costs and contingency to the authorized project budget as a result of the risk assessment process	
Project Definition Rating Index	3	7.9		Complete scope definition to reach at least 266 PDRI score	98.8%

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.7: Schedule Performance for Contractor Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Alignment	3	5.3	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	99.7%
			High	Define the project goals and objectives during FEP	
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			Middle	Use planning tools to promote alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	
Budget Accuracy	5	8.1		Make sure that the accuracy of the budget at the time of authorization should be within from -15% to +20%.	99.8%
Change Management	6	8.5	High	Establish a formal (documented in writing) change management process	99.8%
			High	Specify the change management process in the contract	
			High	Make sure that key project personnel (both owners and contractors) understand the change management process	
			High	Manage changes proactively (timely, hands-on, and aggressive management)	
			High	Negotiate and authorize change orders in a timely manner	
			High	Manage changes proactively (timely, hands-on, and aggressive management) during detail engineering	
			High	Communicate change information to key project participants	
			High	Identify and evaluate areas susceptible to change during review of the project design phase	
			Middle	Manage changes proactively (timely, hands-on, and aggressive management) during construction/ startup	
			Middle	Go through a formal change justification procedure for major changes (i.e., those that exceeded a specified project threshold)	
Front End Planning	7	6.7	High	Organize a skilled and experienced FEP team	99.8%
			High	Organize an authoritative and representative FEP team	
			High	Document the FEP activities	
			High	Communicate the owner's objectives, needs and expectations to the FEP team	
			High	Align the FEP team with the owner's objectives, needs and expectations	
			High	Evaluate the technology during FEP	
			High	Analyze the risk of project alternatives during FEP	
			High	Identify and clarify risk mitigation strategies during FEP	
			High	Use a tool to measure the level of definition	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.8: Safety Performance for Contractor Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Alignment	1	5.8	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	25.0%
			High	Define the project goals and objectives during FEP	
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			High	Use planning tools to promote alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	
Partnering	2	5.1	High	Specify the terms of the contract to support/facilitate the partnering relationship	51.8%
			High	Develop partnering implementation plan jointly	
			High	Assign a partnering champion or sponsor who is responsible for supporting the partnering relationship	
			High	Establish an open environment so that team members can feel free to offer suggestions	
			High	Develop the partnering relationship to facilitate/promote innovation	
			High	Make a collaborate decision on the partnering	
			High	Make sure that an evaluation process should be useful for implementing improvements to the partnering process	
			High	Develop the partnering relationship that includes a shared vision, shared culture, and trust	
			Low	Obtain your company's commitment to partnering	
			Low	Build up your company's experience for partnering	
			Low	Have education and training focusing on how partnering works and benefits	
			Low	Conduct an initial kick off partnering workshop	
			Low	Establish a long-term partnering relationship with the primary contractor	
Team Building	2	7.4	High	Commit your company's resources to formal team building	77.8%
			High	Run a formal team building program	
			High	Make sure that the relevant and representative stakeholders participate in the team building workshop(s)	
			High	Hold a sufficient number of follow up team building meetings to reinforce team building concepts and integrate new team members	
			High	Use an outside consultant or facilitator as part of the team building workshop	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.8: Safety Performance for Contractor Projects (Continued)

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Constructability	2	5.3	High	Assign a full time constructability coordinator to play a major constructability role	92.1%
			High	Apply constructability concepts and principles systematically at the earliest project phase (Early FEP)	
			High	Assign appropriate, knowledgeable construction personnel to effectively interface with appropriate design personnel (design personnel with authority over design issues)	
			High	Integrate the constructability plan into the project execution plan	
			High	Make sure that the engineering deliverables can reflect the recommendations for constructability from construction personnel	
			Middle-High	Provide a full funding for constructability	
			Low	Communicate constructability principles	
			Low	Identify and remove barriers to constructability	
Change Management	5	7.7	High	Establish a formal (documented in writing) change management process	97.0%
			High	Specify the change management process in the contract	
			High	Make sure that key project personnel (both owners and contractors) understand the change management process	
			High	Manage changes proactively (timely, hands-on, and aggressive management)	
			High	Negotiate and authorize change orders in a timely manner	
			High	Manage changes proactively (timely, hands-on, and aggressive management) during construction/ startup	
			High	Communicate change information to key project participants	
			Middle-High	Go through a formal change justification procedure for major changes (i.e., those that exceeded a specified project threshold)	
			Middle-High	Identify and evaluate areas susceptible to change during review of the project design phase	
			Low	Make sure that the owner authorizes before implementation of major changes	
Front End Planning	6	7.0	High	Organize a skilled and experienced FEP team	97.0%
			High	Organize an authoritative and representative FEP team	
			High	Document the FEP activities	
			High	Communicate the owner's objectives, needs and expectations to the FEP team	
			High	Align the FEP team with the owner's objectives, needs and expectations	
			High	Evaluate the technology during FEP	
			High	Analyze the risk of project alternatives during FEP	
			High	Identify and clarify risk mitigation strategies during FEP	
			High	Use a tool to measure the level of definition	
			Low	Complete the final scope definition	
			Low	Align the budget and schedule with the final scope definition	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.9: Quality Performance for Contractor Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Front End Planning	1	5.8	High	Organize an authoritative and representative FEP team	4.8%
			High	Document the FEP activities	
			High	Communicate the owner's objectives, needs and expectations to the FEP team	
			High	Align the FEP team with the owner's objectives, needs and expectations	
			High	Evaluate the technology during FEP	
			High	Analyze the risk of project alternatives during FEP	
			High	Identify and clarify risk mitigation strategies during FEP	
			Middle-High	Organize a skilled and experienced FEP team	
			Low	Make sure that important team members can devote sufficient time to FEP	
Alignment	2	4.2	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	37.0%
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			Middle	Define the project goals and objectives during FEP	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	
Project Definition Rating Index	3	8.2		Complete scope definition to reach at least 238 PDRI score	84.8%
Timely Engineering	4	5.8		Complete more than half of engineering deliverables in time	95.3%
Planning for Startup	5	6.5	High	Define the startup objectives	95.7%
			High	Communicate startup objectives to the relevant project team members	
			High	Allocate adequate resources to planning for startup	
			High	Develop a formal startup execution plan	
			High	Implement a formal startup execution plan	
			High	Identify major startup systems and startup sequences during front end engineering	
			High	Drive the startup schedule by the startup sequence	
			High	Have formal trainings for operator/maintenance	
			High	Develop startup procedures by the intensively involved startup team	
			High	Identify the startup team's roles and responsibilities and communicate them to all project stakeholders	
			High	Use tools or checklists to develop the startup plan and evaluate the extent of startup planning	
			Low-Middle	Develop the system turnover plan	
			Low	Communicate the startup team's roles and responsibilities to all project stakeholders	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

Table 5.10: Business Performance for Contractor Projects

Critical Project Management Attribute	Relative Importance	Minimum Implementation Level		Required Action for Implementation to Achieve Better Cost Performance	Accumulated Probability for Better Performance
Timely Engineering	1	4.3		Complete more than half of engineering deliverables in time	26.7%
Alignment	2	4.7	High	Establish the FEP team leadership for aligning team members effectively to meet project objectives	59.2%
			High	Define the project goals and objectives during FEP	
			High	Communicate the project priorities in terms of cost, schedule and quality	
			High	Communicate the project operations and maintenance philosophy	
			Low	Include all members of the FEP team, relevant internal groups, and contractors in the reward/recognition system	
Change Management	5	7.7	High	Establish a formal (documented in writing) change management process	82.1%
			High	Specify the change management process in the contract	
			High	Make sure that key project personnel (both owners and contractors) understand the change management process	
			High	Manage changes proactively (timely, hands-on, and aggressive management)	
			High	Negotiate and authorize change orders in a timely manner	
			High	Manage changes proactively (timely, hands-on, and aggressive management) during construction/ startup	
			High	Communicate change information to key project participants	
			Middle-High	Go through a formal change justification procedure for major changes (i.e., those that exceeded a specified project threshold)	
			Middle-High	Identify and evaluate areas susceptible to change during review of the project design phase	
			Low	Make sure that the owner authorizes before implementation of major changes	

(Implementation Level: Low, Low-Middle, Middle, Middle-High, High)

5.3 RESEARCH CONTRIBUTIONS

The practical contribution of this study is the original and effective project management implementation guideline that is designed to help practitioners achieve improved performance for both owner and contractor projects. The study offers an optimized implementation guideline tailored to each performance outcome as well as to the implementation environment for a project. The implementation guidelines include the most critical project management attributes, their relative importance and minimum implementation level, and the most effective implementation strategy for each of the project performance outcomes. Necessary actions for implementation are provided along with quantified information, which will be helpful in determining whether or not more effort should be committed to the implementation of project management attributes in accordance with the objectives of a project and the level of resources available.

From an academic point of view, this study designed a data analysis process by a series of statistical analysis methods which can comprehensively investigate the relationships between project management attributes and various project performance outcomes. Most of the studies in the existing literature examined the benefits of a single project management attribute, or provided limited or descriptive analysis results. In this study, several statistical procedures were utilized so that the effects of 19 project management attributes on five project performance outcomes could be quantified in a reasonable and reliable way. This unique analysis process can be used in future research that examines the relationships between project management attributes and project performance outcomes in detail.

5.4 RECOMMENDATIONS FOR FURTHER RESEARCH

Although this research comprehensively analyzed the relationships between five project performance outcomes and 19 project management attributes, the project performance outcomes were categorized into two categories: better or worse. If a large amount of data could be obtained, more than two performance categories could be analyzed, which would help research to quantify the effects of project management attributes on project performance outcome in better detail.

Further research is recommended to examine the interrelationships among project management attributes. In this study, possible indirect effects of project management attributes on project performance were not investigated due to the relatively small number of data. It is obvious that project management attributes implemented at a high-level have a direct effect on project performance. Some of the attributes however, may have only indirect effects on project performance.

Lastly, because new project management attributes are continuously developed by the construction industry, it will be necessary to conduct research at regular intervals so that analysis can cover the effects of newly developed attributes on project performance. The analysis approach presented by this study can be expanded to accommodate new management attributes.

APPENDICES

Appendix A: Questionnaire

(Reorganized from Benchmarking & Metrics Project Level Survey Version 10.3)

General Project Description

General Information

Your Company Name:____
Your Name: ____
Your Title: ____
Please provide the Name that you will use to refer to this Project: ____________
What was your personal role on this project? ___________________________

Project Construction Location:

(State or Province):______________________, Country: ________________

Lead design office location

(State or Province):_______________________,
Country:________________

Division ________________________ (from selection boxes defined by Benchmarking Manager)
Region _____________________________ (from selection boxes defined by Benchmarking Manager)
Sector ____________________________ (from selection boxes defined by Benchmarking Manager)
Business Unit __________________ (from selection boxes defined by Benchmarking Manager)

Contractors answer the next question.

Is the owner of this project ◘ A public sector owner ◘ A private sector owner

Project Description

Which of the following best describes industry group for this project?

- ☐ Heavy Industrial
- ☐ Light Industrial
- ☐ Buildings
- ☐ Infrastructure

Project Nature

From the list below, please select the category that best describes the primary nature of this project. Please see the glossary for definitions.

Which of the following best describes the nature of this project?

- ☐ Grass Roots, Greenfield
- ☐ Brownfield
- ☐ Modernization, Renovation, Upgrade
- ☐ Addition, Expansion
- ☐ Other Project Nature (Please describe): ________________

Project Drivers

Please select the primary driver influencing the execution of this project. Assume safety is a given for all projects.

The primary driver for this project was:

- ☐ Cost
- ☐ Schedule
- ☐ Quality
- ☐ Risk
- ☐ Operability

Project Delivery Method

Please choose the project delivery system from those listed below that most closely characterizes the delivery system used for this project. If more than one delivery system was used, select the primary system.

	Delivery Method	**Description**
◘	Traditional Design-Bid-Build	Serial sequence of design and construction phases; Owner contracts separately with designer and constructor.
◘	Design-Build (or EPC)	Owner contracts with Design-Build (or EPC) contractor.
◘	CM at Risk	Owner contracts separately with designer and CM at Risk. CM holds the contracts.
◘	Multiple Design-Build	Owner contracts with two or more Design-Build (or EPC) contractors, one or more each for process and facilities.
◘	Parallel Primes	Owner contracts separately with designer and multiple prime constructors.

Did you use a Construction Manager not at Risk in conjunction with the selected delivery system?

No	Yes
◘	◘

Project Complexity

Please choose a rating below that best describes the level of complexity for this project, compared to other projects within the same industry sector as this project (e.g., heavy industrial, light industrial, building, infrastructure). Use the definitions below as general guidelines.

- **Low** - Characterized by the use of well established, proven technology, a relatively small number of process steps, a relatively small facility size or process capacity, a facility configuration or geometry that your company has used before, well established, proven construction methods.
- **Average –** Characterized by the use of established technology, a moderate number of process steps, a moderate facility size or process capacity, facility configuration or geometry that your company has used before, established, proven construction methods.
- **High**- Characterized by the use of new, “unproven” technology, an unusually large number of process steps, large facility size or process capacity, new facility configuration or geometry, new construction methods.

Low			Average			High
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Project Performance Outcomes

Budgeted and Actual Project Costs by Function

Please indicate the Budgeted (Baseline) Cost, Contingency, Contingency spent, and Actual Project Costs in the table below.

1. Click on the project function links for function definitions and typical cost elements.
2. If this project did not include a particular function, please select N/A for Not Applicable.
3. **If you know total project costs but have incomplete function information**, you may enter as much function information as you know and override the automatic totaling by manually filling in the total project cost. As long as you don't click back into a function field, your total will be accepted and recorded.
4. **Enter cost in U.S. Dollars. If currency conversion is required use the exchange rate at the midpoint of construction schedule.**

Owner Instructions
Budget amounts include contingency and correspond to funding approved **at time of authorization.** This is the original baseline budget, and should **not be updated** to include any changes since change data are collected in a later section. Metrics definitions specifically address changes as appropriate. The total project **budget** amount should include all **planned expenses (excluding** the cost of land**)** from Front-end Planning through startup, including amounts estimated for in-house salaries, overhead, travel, etc. The total **actual** project cost should include all **actual** project costs **(excluding** the cost of land**)** from Front-end Planning through startup, including amounts expended for in-house salaries, overhead, travel, etc.

***Contractor Instructions*: Only enter data for your scope of work**
Only enter cost data for your scope of work. Budget amounts should include contingency and correspond to the estimate **at time of contract award**. This is the original baseline budget, and should **not be updated** to include any changes since change data are collected in a later section. Metrics definitions specifically address changes as appropriate. The total project **budget** amount should be the **planned expenses** of all functions performed by your company, including amounts for in-house salaries, overhead, travel, etc., but excluding the cost of land. The total **actual** project cost should be the **actual** project costs for functions performed by your company including amounts expended for in-house salaries, overhead, travel, etc., but excluding the cost of land.

Project Function	Baseline Budget (Including Contingency)	Amount of Contingency in Budget	Actual Cost
Front-end Planning	$___________	$___________	$___________
	◘ NA ◘ Don't Know	◘NA ◘Don't Know	◘NA ◘ Don't Know
Detail Engineering	$___________	$___________	$___________
	◘ NA ◘ Don't Know	◘NA ◘ Don't Know	◘NA ◘ Don't Know
Procurement	$___________	$___________	$___________
	◘ NA ◘ Don't Know	◘NA ◘ Don't Know	◘NA ◘ Don't Know
Construction	$___________	$___________	$___________
	◘NA ◘ Don't Know	◘NA ◘ Don't Know	◘NA ◘ Don't Know
Startup	$___________	$___________	$___________
	◘NA ◘ Don't Know	◘NA ◘ Don't Know	◘NA ◘ Don't Know
Total Project	$___________	Total Contingency $___________	$___________

Does the baseline budget include contingency?		
Yes	No	Don't know
◘	◘	◘
Total Contingency Spent $_______________		

Cost of Project Development and Scope Changes

Please record the **approved** changes to your project by phase in the table provided below. For each phase indicate the net cost impact resulting from **approved** project development changes and scope changes. Either the owner or contractor may initiate changes.

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

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

1. **For contractors,** please only enter data for your scope of work.
2. Changes should be reported for the time period in which they were initiated. **If you can only provide total amounts, please indicate Don't Know in the pre-construction and construction through startup rows and indicate the total amounts in the totals row.** As long as you don't click back into a detail information row, your total will be accepted and recorded.
3. Indicate whether the net impact was a (-) decrease or an (+) increase by indicating a negative number for a decrease and a positive number for an increase. If no change orders were granted during a phase, please enter zero.

Project Phase	Cost Increase (+) / Decrease (-) of Project Development Changes	Cost Increase (+) / Decrease (-) of Scope Changes
Pre-Construction	$___ ◘ Don't Know	____ ◘ Don't Know
Construction thru Startup	$____ ◘ Don't Know	____ ◘ Don't Know
Totals	$____	$___

Cost of Field Rework

Did you track the cost impact of field rework for this project?

◘Yes ◘No ◘ Don't Know

1. ***If you tracked field rework, indicate the Direct Cost***. The direct cost of field rework relates to all costs needed to perform the rework itself (this does not include indirect costs).

2. If there was no direct cost or schedule impact of field rework, please enter "0".

Direct Cost of Field Rework: $___________

Planned and Actual Project Schedule

Please indicate your company's Planned Baseline and Actual Project Schedule by function:

1. Click on the project function links below for a description of starting and stopping points for each function.
2. If this project did not include a particular function please select N/A.
3. **If you have incomplete function information**, you must enter overall project start and stop dates. Please enter as much function information as possible.

Owner Instructions:

The dates for the planned schedule should be those in effect **at– project authorization.** If you cannot provide an exact day for either the planned or actual, estimate to the nearest week.

Contractor Instructions: Only enter data for your scope of work

Enter schedule data only for your scope of work on this project. The dates for the planned schedule should be those in effect **at the estimate time of contract award**. If you cannot provide an exact day for either the planned or actual, estimate to the nearest week.

Project Function	Baseline Schedule		Actual Schedule	
	Start mm/dd/yyyy	Stop mm/dd/yyyy	Start mm/dd/yyyy	Stop mm/dd/yyyy
Front-end Planning	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA
Detailed Engineering	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA
Procurement	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA
Construction	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA
Startup	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA
Overall Project Start and Stop Dates	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA	◘Don't Know ◘ NA

Work Stoppages

Were there any uncontrollable or unanticipated work stoppages on this project (this does not include project changes)?

◘ Yes ◘ No ◘ Don't' Know

If yes, what was the total duration in weeks of any uncontrollable or unanticipated work stoppages?

____________________ number of weeks ◘ Don't Know

Please explain the reason(s) for the work stoppage(s)

____

____

____

____

____

Schedule Impact of Project Development and Scope Changes

Please record the **approved** changes to your project by phase in the table provided below. For each phase indicate the **net schedule impact** resulting from **approved** project development changes and scope changes. Either the owner or contractor may initiate changes.

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

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

1. **For contractors,** please only enter data for your scope of work.
2. Changes should be reported for the time period in which they were initiated. **If you can only provide total amounts, please indicate Don't Know in the pre-construction and construction through startup rows and indicate the total amounts in the totals row.** As long as you don't click back into a detail information row, your total will be accepted and recorded.
3. Indicate whether the net impact was a (-) decrease or an (+) increase by indicating a negative number for a decrease and a positive number for an increase. If no change orders were granted during a phase, please enter zero.

Project Phase	Schedule Increase (+) / Decrease (-) of Project Development Changes (weeks)	Schedule Increase (+) / Decrease (-) of Scope Changes (weeks)
Pre-Construction	__________ ◘ Don't Know	__________ ◘ Don't Know
Construction thru Startup	__________ ◘ Don't Know	__________ ◘ Don't Know
Totals	__________	__________

Schedule Impact of Field Rework

Did you track schedule impact of field rework for this project?

◘Yes ◘No ◘ Don't Know

1. ***If you tracked field rework, indicate the schedule impact in weeks*** If there was no schedule impact from field rework, please enter "0".

Schedule impact of Field Rework: $___________

What was the <u>primary</u> source of rework on this project?
◘ Design ◘ Construction ◘ Suppliers ◘ Owner ◘ Don't Know

Achieving Facility Capacity

Contractor only:
Were you involved in start up activities?

No	Yes	Don't Know
◘	◘	◘

If contractor did not perform start up activities, skip the rest of this section.

Answer the next two questions for heavy or light industrial projects only.

What percent of initial planned capacities were achieved during Startup?

______% ◘ Don't Know

To what extent were product quality specifications achieved?

Not at All			Moderately			Fully Achieved	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Answer the next question for building projects only

To what extent was the planned functionality of the building achieved?

Not at All			Moderately			Fully Achieved	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

To what extent were planned project quality specifications achieved?

Not at All			Moderately			Fully Achieved	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Project Outcomes

Using a scale from 1 to 7, where 1 means "not at all successful" and 7 means "extremely successful" please indicate the overall success of this project in terms of :

Meeting cost expectations

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Meeting schedule expectations

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Meeting safety expectations

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Meeting business objectives

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Meeting quality goals

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Using a 1 to 7 scale where 1 means "not at all effective" and 7 means "extremely effective", please indicate how effective the following were on this project:

Project teamwork

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Project team communications

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

For contractors only
Your working relationship with the owner

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

For owners only
Your working relationship with the primary contractor

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

To what extent do you believe that the key project team members understood the owner's goals and objectives of this project

Not at All Successful			Moderately Successful			Extremely Successful
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Projects invariably differ in a variety of ways. Please indicate in the space below what you found to be particular challenges or difficulties on this project, compared to other comparable projects on which you have worked.

____

____

____

What do you think could have improved this project?

____

____

____

Please indicate the total expected dollar amount of claims pending at project completion.

$________ ◘ Don't Know

Workhours and Accident Data

In the spaces below, please record the **Total OSHA Number of Recordable Incident Cases.** Also record the **Total Number of OSHA DART Cases.**

Next please record the **Total Site Workhours,** the **Percentage of Overtime Hours, and the number of Worker Compensation Claims.**

1. Use the U.S. Department of Labor's OSHA definitions for recordable injuries among this project's workers. If you do not track in accordance with these definitions, click Don't Know in the boxes below.
2. A consolidated project OSHA 300 log is the best source for the data.

Total OSHA Number of Recordable Incident Cases (Injuries, Illnesses, Fatalities, Transfers and Restrictions)	TOTAL Number of OSHA DART Cases (Days Away, Restricted or Transferred)
___________ Total Recordables ◘ Don't Know	_______________ **Total DART Cases** ◘ Don't Know
Total Site Workhours ____________________ ◘ Don't Know	
Percentage of Overtime Hours What percentage of the workhours were "**overtime**" - above your normal work week? If the actual percentage cannot be calculated, please provide your best assessment. Answer Don't Know only if you cannot make a reasonable assessment. _______________(%) ◘ Don't Know	
Please indicate the number of Workman Compensation Claims on this project. _______________ ◘ Don't Know	

Project Management Attributes

The following Attributes sections include questions about attributes implemented on this project. Please respond to every Attribute. If a project did not implement a certain attribute, indicate as such and skip to the next section.

Front-End Planning

Front-End Planning involves the process of developing sufficient strategic information such that owners can address risk and decide to commit resources to maximize the chance for a successful project. Front-End Planning includes putting together the project team, selecting technology, selecting the project site, developing project scope, and developing project alternatives. Front-End Planning is often perceived as synonymous with front-end loading, pre-project planning, feasibility analysis, and conceptual planning.

For contractors only

Did your company participate in the Front-End Planning effort?
◘ Yes, as a front-end planner for the owner
◘ No, my company did not participate in the front-end planning effort.

Select a score below that best describes the skill and experience of the Front-End Planning team. **Please use the scale and definitions provided.**

Excellent – Generally highly skilled and experienced members

Adequate – Generally adequately skilled and experienced members

Poor – Generally, members with a poor combination of skill or experience

Poor			Adequate			Excellent	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Select a score below that best describes the authority and representation of the Front-End Planning team. **Please use the scale and definitions provided.**

Excellent - Appropriate authority; excellent representation from business, project management, technical disciplines, and operations; always able to respond effectively to business and project objectives.

Adequate – Adequate authority; adequate representation from business, project management, technical disciplines, and operations; usually able to respond effectively to business and project objectives.

Poor - Inadequate authority; insufficient representation from business, project management, technical disciplines, and operations; generally unable to respond to business and project objectives.

Poor			Adequate			Excellent	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

In your opinion, how well defined were the roles and responsibilities of the Front-End Planning Team members?

Poorly Defined		Moderately Well Defined				Very Well Defined	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How would you assess the effectiveness of communication among the Front-End Planning Team members?

Not at all Effective		Somewhat Effective				Very Effective	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Please assess the quality and completeness of the Front-End Planning documentation?

Poor			Adequate			Excellent	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Please indicate the extent to which you agree or disagree with the following statements.

"The owner's objectives, needs and expectations were clearly communicated to the Front-End Planning Team."

◘ Strongly Agree
◘ Agree
◘ Neutral
◘ Disagree
◘ Strongly Disagree
◘ Don't Know

"The Front-End Planning Team was well aligned in terms of the owner's objectives, needs and expectations."

◘ Strongly Agree
◘ Agree
◘ Neutral
◘ Disagree
◘ Strongly Disagree
◘ Don't Know

Select a score below that best describes the technology evaluation performed for this project during Front-End Planning. **Please use the scale and definitions provided.**

Excellent - Thorough and detailed identification and analysis of existing and emerging technologies (either process technologies and/or building technologies) for feasibility and compatibility with corporate business and operations objectives. Scale-up problems and hands-on process experience were evaluated.

Adequate –A cursory identification and analysis of existing and emerging technologies (either process technologies and/or building technologies) for feasibility and compatibility with corporate business and operations objectives. Scale-up problems and hands-on process experience were considered.

Poor - Weak or no technology evaluation.

Poor			Adequate			Excellent	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Using the scale and definitions below, please assess the Front-End Planning evaluation of alternate siting locations.

Excellent - Thorough and detailed assessment of relative strengths and weaknesses of alternate locations to meet owner requirements.

Adequate – A cursory assessment of the relative strengths and weaknesses of alternate locations to meet owner requirements.

Poor - Weak or no evaluation of alternate siting locations.

Poor			Adequate			Excellent	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Using the scale and definitions below, please assess the risk analysis of project alternatives performed during Front-End Planning.

Excellent - Risks associated with the selected project alternatives were clearly identified and thoroughly analyzed. These analyses generally included financial/business, regulatory, project, and operational risk categories and were designed to minimize the impacts of risks on project success.

Adequate – Modest attempt to identify and analyze risks associated with the selected project alternatives. These analyses may have included financial/business, regulatory, project, and operational risk categories and were designed to minimize the impacts of risks on project success.

Poor - Weak or no risk analysis performed during Front-End Planning for project alternatives.

Poor			Adequate			Excellent	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

To what extent were appropriate risk mitigation strategies identified and clarified during Front-End Planning?

Poorly Identified / Clarified			Moderately Well			Comprehensively Identified / Clarified	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Please indicate how well all necessary regulatory permits were addressed during Front-End Planning.

Poorly Addressed			Moderately Well Addressed			Thoroughly Addressed	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Did you use the PDRI or similar instrument to measure the level of definition for this project?

No	Yes	Don't Know
◘	◘	◘

Please assess the completeness of the final scope definition.

Poor			Moderate			Complete	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How well were the budget and schedule aligned with the final scope definition?

Poorly			Adequately			Very Well	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How significant of a problem was the inability of important team members to devote sufficient time to FEP?

◘ A very significant problem that had a substantial negative impact on the team

◘ A significant problem that had a noticeable negative impact on the team

◘ Not much of a problem

◘ Essentially not a problem

◘ Don't Know

Alignment During Front-End Planning

Alignment is the condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives.

How would you evaluate the effectiveness of the Front-End Planning Team leadership for aligning team members to meet project objectives?

Excellent	Very Good	Fair	Poor	Don't Know
◘	◘	◘	◘	◘

How well were the project goals and objectives defined during Front-End Planning

Not at All, Poorly		Moderately Well				Very Well	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Please indicate how much you agree or disagree with each of the following statements.

"The project priorities in terms of cost, schedule and quality were clearly communicated."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

"The Front-End Planning team culture fostered trust, honesty and open communication."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

"Team meetings were effective for gaining alignment on project objectives."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

To what extent was communication in the Front-End Planning process two-way communication?

Always	Mostly	Sometimes	Rarely	Never	Don't Know
◘	◘	◘	◘		◘

How clearly was the project operations and maintenance philosophy communicated?

Not at All, Poorly			Fair			Very Well	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Was there a reward/recognition system used during Front-End Planning to promote team alignment?

No	Yes	Don't Know
◘	◘	◘

Answer if yes, a reward/recognition system was used.

To what extent was the reward/recognition system tied into the overall project objectives and priorities?

- ◘ Directly linked to the project objectives and priorities
- ◘ Loosely related to project objectives and priorities
- ◘ No clear link between rewards/recognition and the objectives and priorities of the project
- ◘ Don't Know

Answer if yes to reward/recognition system used.

Were all members of the Front-End Planning team and relevant internal groups and contractors included in the reward/recognition system?

- ◘ Yes, all members of the FEP team and relevant internal groups and contractors were included
- ◘ Most members of the FEP and relevant internal groups and contractors were included
- ◘ Participation was selective, many were not included
- ◘ Don't Know

Did the Front-End Planning Team use the Alignment Thermometer to evaluate team alignment?

No	Yes	Don't Know
◘	◘	◘

If you answered yes to above,
Please indicate how effective/helpful the use of the Alignment Thermometer was for evaluating and improving team alignment.

Not at All, Effective		Somewhat Effective			Very Effective		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How effective were any planning tools that were used for promoting alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)?

Didn't Use, Not at All, Effective		Somewhat Effective				Very Effective	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Partnering

Partnering is a commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant's resources. This requires changing traditional relationships to a shared culture without regard to organizational boundaries. The relationship is based on trust, dedication to common goals and an understanding of each other's individual expectations and goals.

We want to begin with some questions about your company's commitment to and experience with partnering.

How would you describe your company's overall commitment to partnering?

- ◘ My company is very committed to the partnering concept, from executive management down to project level staff
- ◘ My company is somewhat committed to partnering; that commitment is generally among project level staff; executive management is not very involved
- ◘ My company is not very committed to partnering; it is not often discussed and not often pursued
- ◘ My company is not at all committed to partnering by anyone's definition
- ◘ Don't Know

Please indicate below how you would characterize your company's experience with using partnering.

- ◘ We have a long history of using partnering on most projects as a matter of routine
- ◘ We use partnering on most projects as a matter of routine, but have only recently been doing so
- ◘ We use partnering occasionally on selected projects
- ◘ We rarely use partnering on our projects
- ◘ We do not use partnering at all
- ◘ Don't Know

Skip the rest of this section if you answered not at all to using partnering.

We now want to ask some questions about the partnering relationship for this particular project.

Owner only question

Did you have a partnering agreement on this project with the primary contractor?

No	Yes	Don't Know
◘	◘	◘

Skip the rest of this section if you answered no to above.

Owner only question

Was the primary contractor on this project an organization with whom you have had an existing partnering relationship (i.e., before this particular project?)

No	Yes	Don't Know
◘	◘	◘

Owner only question, respond if yes to above.

How long have you worked in a partnering relationship with this contractor?

Less than one year	1 to 2 years	2 to 5 years	5 to 10 years	More than 10 years	Don't know
◘	◘	◘	◘	◘	◘

Contractor only question
Did you have a partnering agreement on this project with the owner?

No	Yes	Don't Know
◘	◘	◘

Skip the rest of this section if no to above.
Contractor only question
Was the owner on this project an organization with whom you have had an existing partnering relationship (i.e., before this particular project?)

No	Yes	Don't Know
◘	◘	◘

Contractor only question, answer if yes to above.
How long have you worked in a partnering relationship with this owner?

Less than one year	1 to 2 years	2 to 5 years	5 to 10 years	More than 10 years	Don't know
◘	◘	◘	◘	◘	◘

Did the terms of the contract support/facilitate the partnering relationship?

◘ The contract was very supportive of the partnering relationship
◘ The contract was generally supportive of partnering, but some terms were barriers
◘ No, the contract tended to serve as a barrier to effective partnering
◘ Don't Know

Was there a partnering agreement explicitly in the contract or referenced by the contract for this project?

No	Yes	Don't Know
◘	◘	◘

Skip the next question if no to "agreement in contract."

Please indicate which of the following elements were included in the partnering agreement. **Please check all that apply.**

◘ A mission statement for the partnering relationship
◘ Operating principles for the relationship
◘ Specification of expectations of the relationship
◘ Goals and objectives for the relationship
◘ Measures of success by which the services to be provided are judged
◘ Sharing of business plans and other key business information
◘ Incentive provisions to reinforce partnering
◘ Don't Know

Was there a jointly developed partnering implementation plan that was applied to this project?

◘ Yes and it was jointly developed
◘ Yes, there was an implementation plan that was applied to this project, but it was not jointly developed
◘ No, there was no partnering implementation plan applied to this project
◘ Don't Know

Please indicate the extent of education and training on this project that focused on how partnering works and its benefits.

◘ Extensive, formal education directed to the entire partnering organization
◘ Moderate, some educational efforts, but not systematic
◘ Minimal, sporadic and superficial at best
◘ None, no effort
◘ None, no need, since the parties have a well established partnering relationship
◘ Don't Know

Was there a partnering champion or sponsor who was responsible for supporting the partnering relationship?

Yes, a full time commitment	Yes, a part time commitment	No	Don't Know
◘	◘	◘	◘

Was there an initial kick off partnering workshop conducted?

Yes, with an outside facilitator	Yes, with an in-house facilitator	Yes, but without a facilitator	No initial kick off partnering workshop was held	Don't Know
◘	◘	◘		◘

To what extent were social gatherings and other perks provided to the partnering participants?

Routinely	Occasionally	Not too often	Not at all	Don't Know
◘	◘	◘		◘

Please indicate the extent to which you agree or disagree with the following statements.

"Team members felt free to offer suggestions openly."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

"The partnering relationship facilitated/promoted innovation."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

"Decision making on the partnering team was collaborative."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

Was there a method for measuring and evaluating the effectiveness of the work processes of the partnering team?

No	Yes	Don't Know
◘	◘	◘

Answer the next question only if yes to above.
Please indicate how useful this evaluation was for implementing improvements to the partnering process on this project.

Not at All, Useful		Somewhat Useful			Very Useful		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Please indicate the extent to which the partnering relationship was characterized by a shared vision, shared culture, and trust.

Not at All		Somewhat			Very Much So		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Team Building

Team Building is a ***formal*** project-focused process that builds and develops shared goals, interdependence, trust and commitment, and accountability among team members and that seeks to improve team members' problem-solving skills.

Please describe your company's commitment to formal team building. By formal, we mean a documented, systematic, structured process.

◘ My company is very committed to formal team building, from executive management down to project level staff

◘ My company is somewhat committed to formal team building

◘ My company is not too committed to formal team building; there is some focus from time to time on informal team building

◘ My company is not at all committed to team building

◘ Don't Know

Was a formal team building program used on this project?

No	Yes	Don't Know
◘	◘	◘

If no, skip the rest of this section.

What was the earliest point in this project when the formal team building program was implemented?

◘ Front-End Planning

◘ Engineering/Design

◘ Construction

◘ Other (Specify ____________________________)

◘ Don't Know

Some team building programs use one or more "retreat" type workshops where shared goals are developed and essential decision making and dispute resolution procedures are worked out. Please indicate the extent to which this was used on this project.

◘ The team building workshop was quite extensive and targeted decision making and dispute resolution procedures well

◘ The team building workshop was sufficient, but could have focused more on the relevant topics

◘ The building workshop was superficial and insufficient

◘ No team building workshop was held

◘ Don't Know

Skip if no workshop was held.

Was an outside consultant or facilitator used as part of the team building workshop?

◘ Yes, an outside facilitator used at the team building workshop and was very effective

◘ Yes, an outside facilitator used at the team building workshop but was <u>not</u> very effective

◘ An in-house facilitator was used

◘ No, a facilitator was not used at all

◘ Don't Know

Was an outside consultant or facilitator used as part of the team building workshop?

◘ Yes, an outside facilitator used at the team building workshop and was very effective

◘ Yes, an outside facilitator used at the team building workshop but was not very effective

◘ An in-house facilitator was used

◘ No, a facilitator was not used at all

◘ Don't Know

Please indicate the extent to which you agree or disagree with the following statements.
"The relevant stakeholders were represented at the team building workshop(s)."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

"A sufficient number of follow up team building meetings were held to reinforce team building concepts and integrate new team members."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

Were there job site meetings that focused at least in part on team building?

◘ Yes, we had job site meetings on a regular basis that usually had some focus on team building

◘ Yes, we had job site meetings on a regular basis; the focus on team building was sporadic

◘ Job site meetings did not really focus on team building per se

◘ There were no job site meetings

◘ Don't Know

Project Delivery and Contract Strategy

Owner only; contractors automatically skip this entire section

Project Delivery and Contract Strategy involves a structured process of evaluating and prioritizing owner's objectives, reviewing and evaluating delivery methods and contract types, and then determining what is the appropriate delivery method and contract type for this project.

Did you consider alternative project delivery methods for this project?

No	Yes	Don't Know
◘	◘	◘

Skip to last two questions at the end of this section if no or don't know to above

To what extent did the business planning stage of this project include a review of the business objectives and ranking of the relative importance of these objectives?

No Review or Ranking		General Review or Ranking			Systematic, Thorough Review or Ranking		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

To what extent did the business planning stage include a systematic evaluation of strengths and weaknesses of these alternative project delivery methods?

No Evaluation or Superficial		Partial Evaluation			Systematic, Thorough Evaluation		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Were the project delivery methods ranked or prioritized in terms of suitability?

No	Yes	Don't Know
◘	◘	◘

Did you consider alternative contract types for this project?

No	Yes	Don't Know
◘	◘	◘

Were alternative contract types considered for this project for the primary contractor?

No	Yes	Don't Know
◘	◘	◘

To what extent did the business planning stage include a systematic evaluation of strengths and weaknesses of alternative contract types for the primary contractor?

No Evaluation or Superficial		Partial Evaluation			Systematic, Thorough Evaluation		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Were the different project contract types ranked or prioritized in terms of suitability?

No	Yes	Don't Know
◘	◘	◘

Did you use a tool for assisting with the determination of the project delivery method and contract type for this project?

No	Yes	Don't Know
◘	◘	◘

Looking back on this project, knowing what you know now (and absent any statutory restrictions), what do you think would have been the optimal project delivery method for this project?

◘	Design-Build
◘	Design-Bid-Build
◘	CM at Risk
◘	Multiple Design-Build
◘	Parallel Primes
◘	Other (specify) ______________________

Looking back on this project, knowing what you know now (and absent any statutory restrictions), what do you think would have been the optimal contract type for the following functions for this project?			
	Lump Sum	Cost Reimbursable	Other (please describe)
Engineering or design	◘	◘	◘ _____________
Procurement	◘	◘	◘ _____________
Construction and startup	◘	◘	◘ _____________

Constructability

Constructability is the effective and timely integration of construction knowledge into the conceptual planning, design, construction and field operations of a project to achieve the overall project objectives in the best possible time and accuracy, at the most cost-effective levels.

We first want to ask some questions about your company.

How would you characterize your company's corporate constructability program? Please select the description below that best describes your corporate constructability program.

- ◘ Our company has no constructability program
- ◘ Constructability is only casually recognized at the corporate level
- ◘ It is formally recognized on the corporate level, but is generally part of another program
- ◘ It is a stand alone corporate program that is generally on the same level as quality or safety
- ◘ Don't Know

How would you characterize your company's tracking of constructability lessons learned?

- ◘ None
- ◘ Lessons learned are generally conveyed via word of mouth or personal interaction
- ◘ Some individual documentation; primarily post project reviews and reports
- ◘ A system exists for capture and communication of constructability lessons learned
- ◘ There is a formal data base on constructability lessons learned; it involves input from all levels
- ◘ Don't Know

Now we want to focus on this particular project.

Please indicate which statement best describes the role of a constructability coordinator on this project

- ◘ There was no constructability coordinator for this project
- ◘ Part time at most; very limited responsibilities
- ◘ Full or part time with limited responsibilities
- ◘ Full time and played a major constructability role on this project
- ◘ Don't Know

Please indicate the project phases in which constructability concepts and principles were systematically applied.
Please select all that apply.

- ◘ Early in Front-End Planning
- ◘ Late in Front-End Planning
- ◘ Early in Detail Engineering
- ◘ Late in Detail Engineering
- ◘ Beginning of Construction or later
- ◘ Constructability concepts were not systematically applied on this project
- ◘ Don't Know

Please indicate the extent to which you agree or disagree with the following statement regarding the application of constructability concepts on the design of this project.

"Appropriate, knowledgeable construction personnel were able to effectively interface with appropriate design personnel (design personnel with authority over design issues)."

- ◘ Strongly Agree
- ◘ Agree
- ◘ Neutral
- ◘ Disagree
- ◘ Strongly Disagree
- ◘ Don't Know

Which of the following best describes how constructability principles were communicated on this project? (Select only one)

- ◘ No effort to communicate constructability principles
- ◘ Minimum effort through informal means
- ◘ Moderate effort
- ◘ Substantial effort through structured and formal means
- ◘ Don't Know

Was there a formal documented constructability plan for this project?

No	Yes	Don't Know
◘	◘	◘

Answer the next question, if yes to above.
Was the constructability plan integrated into the project execution plan?

Not at All			Variable, Partial			Fully	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Please indicate which of the following best describes how barriers to constructability were addressed on this project.

- ◘ Constructability was not used on this project
- ◘ There were some minor barriers that were easily addressed and corrected
- ◘ There were several significant barriers, some of which were addressed and corrected; but there was some negative impact on the implementation of constructability
- ◘ There were many significant barriers that were not effectively overcome; they prevented effective implementation of constructability
- ◘ Don't Know

To what extent did the constructability team incorporate relevant information from the lessons learned data base into the project execution plan?

- ◘ Not at all; never consulted the lessons learned data base
- ◘ Rarely; no system in place to consult the data base and incorporate information
- ◘ Sometimes; sporadic efforts to consult the data base and incorporate information
- ◘ Routinely; it was a fundamental part of procedure
- ◘ Don't Know

How would you characterize the funding for constructability on this project?

- ◘ Essentially no financial support
- ◘ Modest, some commitment of financial resources
- ◘ Adequate financial commitment
- ◘ Very well funded
- ◘ Don't Know

Please indicate the extent to which you agree or disagree with the following statement.

"The project constructability efforts were periodically evaluated, updated and improved."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
◘	◘	◘	◘		◘

To what extent did the engineering deliverables reflect the recommendations for constructability from construction personnel?

Not at All			Variable, Partial			Fully	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Project Risk Assessment

Project Risk Assessment is the process to identify, assess and manage risk. The project team evaluates risk exposure for potential project impact to provide focus for mitigation strategies.

How would you describe the risk assessment(s) conducted on this project? Please select the statement that best fits.

- ◘ No risk assessment was conducted
- ◘ Informal risk assessment
- ◘ Formal structured risk assessment
- ◘ Don't Know

Skip the rest of this section if no risk assessment was conducted or don't know to above.

At what point during this project was the first formal risk assessment conducted

- ◘ Validation of project feasibility
- ◘ Project definition
- ◘ Decision to proceed
- ◘ Engineering and Design
- ◘ Procurement
- ◘ Construction
- ◘ Commissioning/startup
- ◘ Other (please specify ________________________)
- ◘ No formal risk assessment was conducted
- ◘ Don't Know

How frequently was the risk assessment updated?

- ◘ Updated on a regular basis (at each phase)
- ◘ Updated on a regular basis (at least quarterly)
- ◘ Updated on a regular basis (but less frequently than quarterly)
- ◘ Updated sporadically
- ◘ Not really updated
- ◘ Don't Know

Was an outside facilitator used on this project to assist with risk assessment?

No	Yes, very involved in the risk assessment process	Yes, but only played a limited role	Don't Know
◘	◘	◘	◘

To what extent were all of the necessary, relevant project team members involved in the risk assessment process?

Not at All			Variable, Partial		All Relevant Members were Appropriately Involved		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Which of the following elements did the risk assessment include? **Check all that apply**

◘ Ranking of key risk elements by likelihood of occurrence

◘ Ranking of key risk elements by relative impact

◘ Identifying most significant risks through analysis that combined likelihood of occurrence and relative impact

◘ Identification of mitigation strategies for most significant risks

◘ Don't Know

How well documented was the risk assessment process for this project?

◘ Thoroughly documented

◘ Partially documented

◘ Not well documented

◘ Not documented at all

◘ Don't Know

Was a risk mitigation plan developed?

No, there was no real documented plan prepared	Yes, an itemized risk mitigation plan was prepared that targeted each critical risk	Yes, a general, documented risk mitigation plan was prepared	Don't Know
◘	◘	◘	◘

Answer the next question only if yes to above.

Which of the following were included in the risk mitigation plan? **Check all that apply.**

◘ The likelihood of occurrence of the risk event

◘ The relative impact of the risk event

◘ The specific impact (cost, schedule, quality, scope, etc.) of the risk event

◘ Identification of the mitigation strategy

◘ Relative cost of the mitigation action

◘ Probability of success of the mitigation action

◘ Responsible party and time line for mitigation action

◘ Don't Know

To what extent was the risk mitigation plan updated?

- Updated on a regular basis (at each phase)
- Updated on a regular basis (at least quarterly)
- Updated on a regular basis (but less frequently than quarterly)
- Updated sporadically
- Not really updated
- Don't Know

To what extent was the risk mitigation plan implemented?

Not at All			Partially			Fully	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Were the mitigation costs and contingency added to the authorized project budget as a result of the risk assessment process?

None were added	Partially added	Fully incorporated into budget	Don't Know
◘	◘	◘	◘

Were the schedule impacts of mitigation added to the baseline project schedule as a result of the risk assessment process?

None were added	Partially added	Fully incorporated into schedule	Don't Know
◘	◘	◘	◘

Change Management

Change Management is the process of incorporating a balanced change culture of recognition, planning and evaluation of project changes in an organization to effectively manage project changes.

Was there a formal (documented in writing) change management process for this project?

No	Yes	Don't Know
◘	◘	◘

Skip this section if no or don't know to above.

How clearly was the change management process specified in the project contract?

Not at all Clear, Specific			Moderate Clear, Specific			Very Clear, Specific	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How well would you say key project personnel (both owners and contractors) understood the change management process?

Not at all Clear, Specific		Moderately Well				Very Well	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Would you say that changes on this project generally were proactively managed? By proactively, we mean timely, hands-on, aggressive management.

No	Yes	Don't Know
◘	◘	◘

Answer the next question only if yes to above.

Was the **change management process** used to proactively manage changes on this project? Please answer separately for detailed engineering/design and construction/startup.

	Not at all Used to Proactively Manage Change			Occasionally Used to Proactively Manage Change		Extensively Used to Proactively Manage Change		Don't Know
	1	2	3	4	5	6	7	
Detailed Engineering	◘	◘	◘	◘	◘	◘	◘	◘
Construction and Startup	◘	◘	◘	◘	◘	◘	◘	◘

To what extent were major changes (i.e., those that exceeded a specified project threshold) required to go through a formal change justification procedure?

Not at all		Sometimes				Always	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Was owner authorization required before implementation of major changes?

Not at all		Sometimes				Always	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How well do you think change information was communicated to key project participants?

Poorly		Variable, Some Well, Some Not			Routinely Very Well		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

To what extent were areas susceptible to change identified and evaluated for risk during review of the project design basis?

Not at all		Moderately				Fully	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Did project personnel negotiate and authorize change orders on this project in a timely manner?

Not at all		Sometimes				Always	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Zero Accident Techniques

Zero Accident Techniques include site specific safety programs and implementation, and auditing and incentive efforts to create a project environment and a level of training that embraces the mind set that all accidents are preventable, and that zero accidents are an obtainable goal.

Was there a written site specific safety plan for this project?

No	Yes	Don't Know
◘	◘	◘

Which of the following best describes the time commitment of the site safety supervisor for this project?

No site safety supervisor	Part-time function	Full-time function	Don't Know
◘	◘	◘	◘

Overall how many workers per safety person were typically (i.e., in terms of the average workforce) on site?

Over 200	150 to 200	70 to 150	20 to 70	1 to 20	Don't Know
◘	◘	◘	◘	◘	◘

How extensive was the job-specific safety orientation conducted for new contractor and subcontractor employees?

Not at All, Inadequate			Cursory Orientation			Extensive Orientation
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

◘Don't Know

On average how much ongoing <u>formal</u> safety training did workers receive <u>each month</u>?

None	Less than 1 hour/ month	1 hour to 5 hours/ month	5 hours to 8 hours/ month	More than 8 hours/ month	Don't Know
◘	◘	◘	◘	◘	◘

On average, how often were <u>safety toolbox meetings</u> held?

2 + Times Per Day	Daily	Several time per Week	Weekly	Monthly	None were held	Don't Know
◘	◘	◘	◘	◘	◘	◘

How often were safety audits performed by <u>corporate safety personnel</u>?

Annually or Less frequently	Quarterly	Monthly	Biweekly	Weekly	Never	Don't Know
◘	◘	◘	◘	◘	◘	◘

To what extent were pre-employment substance abuse tests conducted for contractor employees?

Never	Occasionally, for some employees	Usually, for most employees	Always, for every employee	Don't Know
◘	◘	◘	◘	◘

How frequently were contractor employees randomly screened for alcohol and drugs?

Not at all	Once a year	Twice a year	Quarterly	Monthly or more	Don't Know
◘	◘	◘	◘	◘	◘

How often were near-misses formally (i.e., written documentation) investigated?

Never			Sometimes			Always	Don't Know	None Occurred
1	2	3	4	5	6	7	7	
◘	◘	◘	◘	◘	◘	◘	◘	◘

To what extent were safety incentives used that were based upon zero injury objectives?

Not at All			Moderately			Extensively
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

◘Don't Know

To what extent was safety performance utilized as a criterion for contractor /subcontractor selection?

Not at All			Moderately			Extensively
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

◘Don't Know

To what extent were safety risks systematically identified in the pre-construction phases of this project?

Not at All			Moderately			Extensively
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

◘Don't Know

Planning for Startup

For Heavy and Light Industrial Projects Only
Startup is the transitional phase between plant construction completion and commercial operations, including all of the activities that bridge these two phases. **Planning for Startup** consists of a sequence of activities that begins during requirements definition and extends through initial operations. This section assesses the level of Startup Planning by evaluating the degree of implementation of specific activities throughout the various phases of a project.

Contractor only question.
Was your company responsible for startup?

Yes, full responsibility	Yes, partial responsibility	No, not responsible at all
◘	◘	◘

If no, contractor should skip the rest of this section

How well were the startup objectives defined?

Not at All Well		Moderately Well Defined			Very Well Defined		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Please indicate how well startup objectives were communicated to the relevant project team members.

Not at All Well		Moderately Well Communicated			Very Well Communicated		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How would you characterize the allocation of resources to <u>planning</u> for startup?

Not at All Adequate		Modest, Barely Adequate			Fully Resourced		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How clearly were the startup team's roles and responsibilities <u>identified</u>?

Not at All Clearly		Somewhat Clearly			Very Clearly Identified		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How clearly were the startup team's roles and responsibilities <u>communicated</u> to all project stakeholders?

Not at All Clearly		Somewhat Clearly			Very Clearly Communicated		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

To what extent was a <u>formal</u> startup execution plan developed?

Not at All Developed		Partially Developed			Very Extensively Developed		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

To what extent was a formal startup execution plan implemented?

Not at All Implemented		Partially Implemented			Very Extensively Implemented		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Was the startup execution plan kept current (i.e., reflecting any new project information or scope changes)?

◘ It was routinely updated to incorporate significant new project information or scope changes

◘ It was occasionally updated, but not always kept current

◘ No, it was not updated

◘ It was not updated because there were no significant project changes

◘ Don't Know

How well were major startup systems and startup sequences identified during front-end engineering?

Not at All Identified		Partially Identified			Very Extensively Identified		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

To what extent was the startup schedule driven by the startup sequence (i.e., the necessity of some systems being started before others)?

Not at All Driven		Partially Driven			Primarily Driven by Startup Sequence		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

To what extent were startup needs incorporated into the procurement requirements?

Not at All Incorporated		Partially Incorporated			Fully Incorporated		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Please indicate the ***earliest time period*** of the first project meeting that explicitly and systematically focused on planning for startup. Place a check below for the ***earliest time period***

Front-End Planning			Detail Engineering/ Procurement			Construction			Don't Know
Early	Middle	Late	Early	Middle	Late	Early	Middle	Late	
◘	◘	◘	◘	◘	◘	◘	◘	◘	◘

Please indicate when the startup plan was initially developed?

Front-End Planning			Detail Engineering/ Procurement			Construction			Don't Know
Early	Middle	Late	Early	Middle	Late	Early	Middle	Late	
◘	◘	◘	◘	◘	◘	◘	◘	◘	◘

Please indicate when the startup team was <u>initially</u> assembled?

Front-End Planning			Detail Engineering/ Procurement			Construction			Don't Know
Early	Middle	Late	Early	Middle	Late	Early	Middle	Late	
◘	◘	◘	◘	◘	◘	◘	◘	◘	◘

How often were startup risks assessed?

Not at All		Periodically			Continuously		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How would you characterize the extent of <u>formal</u> operator/maintenance training?

No Formal Training		Moderate Amount of Formal Training			Extensive Formal Training		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Were any tools or checklists used to assist with startup planning? **Check all that apply.**

◘ Yes, we used a tool that helped us develop the startup plan

◘ Yes, we used a tool to evaluate the extent of startup planning

◘ No, we did not use any tools or checklists for startup planning

◘ Don't Know

How would you characterize the system turnover plan?

Not at All Adequate		Moderately Adequate				Excellent	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How involved was the startup team in developing startup procedures?

Not at All Involved		Moderately Involved			Intensively Involved		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

How well were Process Safety Management procedures communicated to the operations and maintenance personnel?

Poorly		Moderately Well			Very Well		Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Budget Accuracy

Thinking back to the time of authorization, what was your assessment of the accuracy of the estimated budget (including contingency) at that time?   Please indicate which category below best describes your assessment of the accuracy of the budget at the time of authorization.

-10 to +10 %	-15 to +20 %	20 to +30 %	30 to +50 %	50 to +100 %	Don't Know
◘	◘	◘	◘	◘	◘

Percent Design Completion

What percentage of the total engineering workhours for design were completed prior to total project budget authorization? __________ % ◘ Unknown

What percentage of the total engineering workhours for design were completed prior to start of the construction phase? __________ % ◘ Unknown

Percent Modularization

Modular construction is a method for constructing unit of a project remote from the final project site. Modularization brings the advantage of the manufacturing processes to the construction industry.
Choose a percentage value that best describes the level of modularization (offsite construction) used. This value should be determined as a ratio of the cost of all modules divided by total installed cost. Include all costs for transportation, setting and hooking up field connections.

◘	◘	◘	◘	◘	◘	◘	◘	◘	◘	◘
0%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**

Fast Track

A method of project delivery in which the sequencing of construction activities enables some portions of the project to begin before the design is completed on other portions of the project.

Was this a fast track project?

No	Yes
◘	◘

Alliance

Active alliances typically involve better communication, cooperation, and trust, as well as more risk sharing. To what extent was this alliance with the primary contractor or the owner an active alliance versus just an alliance "on paper"?

Essentially an Alliance "on paper"			A Moderately Active Alliance			A Very Active Alliance	Don't Know
1	2	3	4	5	6	7	
◘	◘	◘	◘	◘	◘	◘	◘

Engineering Deliverables

Please provide information about this project's use of engineering standards and specifications.

Process Industry Attributes (PIP) is a consortium of process industry owners and engineering/ construction contractors who serve the industry. PIP publishes "Attributes" that reflect standards in many engineering disciplines.

	Source of Standards and Specifications	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**NA / UNK**
		0	**1**	**2**	**3**	**4**	
A	The project was executed with internal owner engineering standards and specifications.	◘	◘	◘	◘	◘	◘
B	The project was executed with contractor engineering standards and specifications.	◘	◘	◘	◘	◘	◘
C	The project was executed using industry consortia engineering attributes for standards and specifications.	◘	◘	◘	◘	◘	◘
D	The project was executed using Process Industry Attributes (PIP) standards and specifications.	◘	◘	◘	◘	◘	◘

Were engineering deliverables released in a timely manner?

Seldom			Sometimes			Always
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

◘ Don't Know

To what extent were the engineering deliverables complete and accurate (with minimal errors and omissions)?

Seldom Complete and Accurate			Sometimes Complete and Accurate			Always Complete and Accurate
1	2	3	4	5	6	7
◘	◘	◘	◘	◘	◘	◘

Project Definition Rating Index

<Building Projects>

Please complete the following matrix using the ***appropriate definition levels*** given below. Indicate how well defined each element was ***prior to the total project budget authorization*** by selecting the appropriate definition level.

1. Complete definition
2. Minor deficiencies
3. Some deficiencies
4. Major deficiencies
5. Incomplete or poor definition
6. Not Applicable
7. Unknown

Note: If this is an infrastructure project some of the following elements may not apply to your project. Please fill in "Not Applicable" to indicate if any element does not apply to your project.

A. Business Strategy	**(1) Complete <---------->Poor (5)**						
A1. Building Use	1	2	3	4	5	NA	UNK
	◘	◘	◘	◘	◘	◘	◘
A2. Business Justification	1	2	3	4	5	NA	UNK
	◘	◘	◘	◘	◘	◘	◘
A3. Business Plan	1	2	3	4	5	NA	UNK
	◘	◘	◘	◘	◘	◘	◘
A4. Economic Analysis	1	2	3	4	5	NA	UNK
	◘	◘	◘	◘	◘	◘	◘
A5. Facility Requirements	1	2	3	4	5	NA	UNK
	◘	◘	◘	◘	◘	◘	◘
A6. Future Expansion/Alternate Consideration	1	2	3	4	5	NA	UNK
	◘	◘	◘	◘	◘	◘	◘
A7. Site Selection Consideration	1	2	3	4	5	NA	UNK
	◘	◘	◘	◘	◘	◘	◘
A8. Project Objectives Statement	1	2	3	4	5	NA	UNK
	◘	◘	◘	◘	◘	◘	◘

B. Owner Philosophies	(1) Complete <---------->Poor (5)					
	1	2	3	4	5	NA	UNK
B1. Reliability Philosophy	☐	☐	☐	☐	☐	☐	☐
B2. Maintenance Philosophy	☐	☐	☐	☐	☐	☐	☐
B3. Operating Philosophy	☐	☐	☐	☐	☐	☐	☐
B4. Design Philosophy	☐	☐	☐	☐	☐	☐	☐
C. Project Requirements	**(1) Complete <---------->Poor (5)**						
	1	2	3	4	5	NA	UNK
C1. Value-Analysis Process	☐	☐	☐	☐	☐	☐	☐
C2. Project Design Criteria	☐	☐	☐	☐	☐	☐	☐
C3. Evaluation of Existing Facilities	☐	☐	☐	☐	☐	☐	☐
C4. Scope of Work Overview	☐	☐	☐	☐	☐	☐	☐
C5. Project Schedule	☐	☐	☐	☐	☐	☐	☐
C6. Project Cost Estimate	☐	☐	☐	☐	☐	☐	☐
D. Site Information	**(1) Complete <---------->Poor (5)**						
	1	2	3	4	5	NA	UNK
D1. Site Layout	☐	☐	☐	☐	☐	☐	☐
D2. Site Surveys	☐	☐	☐	☐	☐	☐	☐
D3. Civil/Geotechnical Information	☐	☐	☐	☐	☐	☐	☐
D4. Governing Regulatory Requirements	☐	☐	☐	☐	☐	☐	☐
D5. Environmental Assessment	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	NA	UNK
D6. Utility Sources with Supply Conditions	◘	◘	◘	◘	◘	◘	◘
D7. Site Life Safety Considerations	◘	◘	◘	◘	◘	◘	◘
D8. Special Water and Waste Treatment Requirements	◘	◘	◘	◘	◘	◘	◘
E. Building Programming	**(1) Complete <---------->Poor (5)**						
E1. Program Statement	◘	◘	◘	◘	◘	◘	◘
E2. Building Summary Space List	◘	◘	◘	◘	◘	◘	◘
E3. Overall Adjacency Diagrams	◘	◘	◘	◘	◘	◘	◘
E4. Stacking Diagrams	◘	◘	◘	◘	◘	◘	◘
E5. Growth and Phased Development	◘	◘	◘	◘	◘	◘	◘
E6. Circulation and Open Space Requirements	◘	◘	◘	◘	◘	◘	◘
E7. Functional Relationship Diagrams/Room by Room	◘	◘	◘	◘	◘	◘	◘
E8. Loading/Unloading/Storage Facilities Requirements	◘	◘	◘	◘	◘	◘	◘
E9. Transportation Requirements	◘	◘	◘	◘	◘	◘	◘
E10. Building Finishes	◘	◘	◘	◘	◘	◘	◘
E11. Room Data Sheets	◘	◘	◘	◘	◘	◘	◘
E12. Furnishings, Equipment, and Built-Ins	◘	◘	◘	◘	◘	◘	◘
E13. Window Treatment	◘	◘	◘	◘	◘	◘	◘

F. Building/Project Design Parameters	(1) Complete <---------->Poor (5)					
F1. Civil/Site Design	1	2	3	4	5	NA	UNK
F2. Architectural Design	1	2	3	4	5	NA	UNK
F3. Structural Design	1	2	3	4	5	NA	UNK
F4. Mechanical Design	1	2	3	4	5	NA	UNK
F5. Electrical Design	1	2	3	4	5	NA	UNK
F6. Building Life Safety Requirements	1	2	3	4	5	NA	UNK
F7. Constructability Analysis	1	2	3	4	5	NA	UNK
F8. Technological Sophistication	1	2	3	4	5	NA	UNK
G. Equipment	**(1) Complete <---------->Poor (5)**						
G1. Equipment List	1	2	3	4	5	NA	UNK
G2. Equipment Location Drawings	1	2	3	4	5	NA	UNK
G3. Equipment Utility Requirements	1	2	3	4	5	NA	UNK
H. Procurement Strategy	**(1) Complete <---------->Poor (5)**						
H1. Identify Long-Lead/Critical Equip. and Materials	1	2	3	4	5	NA	UNK
H2. Procurement Procedures and Plans	1	2	3	4	5	NA	UNK

J. Deliverables	**(1) Complete <---------->Poor (5)**						
J1. CADD/Model Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
J2. Documentation/Deliverables	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
K. Project Control	**(1) Complete <---------->Poor (5)**						
K1. Project Quality Assurance and Control	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
K2. Project Cost Control	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
K3. Project Schedule Control	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
K4. Risk Management	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
K5. Safety Procedures	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
L. Project Execution Plan	**(1) Complete <---------->Poor (5)**						
L1. Project Organization	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
L2. Owner Approval Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
L3. Project Delivery Method	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
L4. Design/Construction Plan & Approach	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
L5. Substantial Completion Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘

<Industrial Projects>

Please complete the following matrix using the ***appropriate definition levels*** given below. Indicate how well defined each element ***was prior to the total project budget authorization*** by selecting the appropriate definition level.

Note: If this is an infrastructure project some of the following elements may not apply to your project. Please fill in "Not Applicable" to indicate if any element does not apply to your project.

Industrial PDRI	***Definition Level at Authorization***						
A. Manufacturing Objectives Criteria	**(1) Complete <---------->Poor (5)**						
A1. Reliability Philosophy	1	2	3	4	5	NA	UNK
A2. Maintenance Philosophy	1	2	3	4	5	NA	UNK
A3. Operating Philosophy	1	2	3	4	5	NA	UNK
B. Business Objectives	**(1) Complete <---------->Poor (5)**						
B1. Products	1	2	3	4	5	NA	UNK
B2. Market Strategy	1	2	3	4	5	NA	UNK
B3. Project Strategy	1	2	3	4	5	NA	UNK
B4. Affordability/Feasibility	1	2	3	4	5	NA	UNK
B5. Capacities	1	2	3	4	5	NA	UNK
B6. Future Expansion Considerations	1	2	3	4	5	NA	UNK
B7. Expected Project Life Cycle	1	2	3	4	5	NA	UNK
B8. Social Issues	1	2	3	4	5	NA	UNK

C. Basic Data Research & Development	**(1) Complete <---------->Poor (5)**						
C1. Technology	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
C2. Processes	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
D. Project Scope	**(1) Complete <---------->Poor (5)**						
D1. Project Objectives Statement	Yes ◘	No ◘	NA ◘	UNK ◘			
D2. Project Design Criteria	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
D3. Site Characteristics Available vs. Required	Yes ◘	No ◘	NA ◘	UNK ◘			
D4. Dismantling and Demolition Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
D5. Lead/Discipline Scope of Work	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
D6. Project Schedule	Yes ◘	No ◘	NA ◘	UNK ◘			
E. Value Engineering	**(1) Complete <---------->Poor (5)**						
E1. Process Simplification	Yes ◘	No ◘	NA ◘	UNK ◘			
E2. Design & Material Alternatives	Yes ◘	No ◘	NA ◘	UNK ◘			
E3. Design for Constructability Analysis	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘

F. Site Information	(1) Complete <---------->Poor (5)						

F1. Site Location	Yes	No	NA	UNK
	◘	◘	◘	◘

	1	2	3	4	5	NA	UNK
F2. Surveys & Soil Tests	◘	◘	◘	◘	◘	◘	◘
F3. Environmental Assessment	◘	◘	◘	◘	◘	◘	◘
F4. Permit Requirements	◘	◘	◘	◘	◘	◘	◘
F5. Utility Sources with Supply Conditions	◘	◘	◘	◘	◘	◘	◘
F6. Fire Protection & Safety Considerations	◘	◘	◘	◘	◘	◘	◘
G. Process/Mechanical	**(1) Complete <---------->Poor (5)**						
G1. Process Flow Sheets	◘	◘	◘	◘	◘	◘	◘
G2. Heat & Material Balances	◘	◘	◘	◘	◘	◘	◘
G3. Piping & Instrumentation Diagrams	◘	◘	◘	◘	◘	◘	◘
G4. Process Safety Management	◘	◘	◘	◘	◘	◘	◘
G5. Utility Flow Diagrams	◘	◘	◘	◘	◘	◘	◘
G6. Specifications	◘	◘	◘	◘	◘	◘	◘
G7. Piping System Requirements	◘	◘	◘	◘	◘	◘	◘
G8. Plot Plan	◘	◘	◘	◘	◘	◘	◘
G9. Mechanical Equipment List	◘	◘	◘	◘	◘	◘	◘

G10. Line List	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
G11. Tie-In List	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
G12. Piping Specialty Items List	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
G13. Instrument Index	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
H. Equipment Scope	**(1) Complete <---------->Poor (5)**						
H1. Equipment Status	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
H2. Equipment Location Drawings	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
H3. Equipment Utility Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
I. Civil, Structural, & Architectural	**(1) Complete <---------->Poor (5)**						
I1. Civil/Structural Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
I2. Architectural Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
J. Infrastructure	**(1) Complete <---------->Poor (5)**						
Water Treatment Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
J2. Loading/Unloading/Storage Facilities Requirements	1 ◘	2 ◘	3 ◘	4 ◘	5 ◘	NA ◘	UNK ◘
J3. Transportation Requirements	Yes ◘	No ◘	NA ◘	UNK ◘			

K. Instrument & Electrical	(1) Complete <---------->Poor (5)
K1. Control Philosophy	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘
K2. Logic Diagrams	Yes ◘ / No ◘ / NA ◘ / UNK ◘
K3. Electrical Area Classifications	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘
K4. Substation Requirements Power Sources Identification	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘
K5. Electric Single Line Diagrams	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘
K6. Instrument & Electrical Specifications	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘

L. Procurement Strategy	(1) Complete <---------->Poor (5)
L1. Identify Long Lead/Critical Equip. & Materials	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘
L2. Procurement Procedures and Plans	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘
L3. Procurement Responsibility Matrix	Yes ◘ / No ◘ / NA ◘ / UNK ◘
M. Deliverables	**(1) Complete <---------->Poor (5)**
M1. CADD/Model Requirements	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘
M2. Deliverables Defined	1 ◘ / 2 ◘ / 3 ◘ / 4 ◘ / 5 ◘ / NA ◘ / UNK ◘
M3. Distribution Matrix	Yes ◘ / No ◘ / NA ◘ / UNK ◘

N. Project Control	(1) Complete <---------->Poor (5)						
N1. Project Control Requirements	1	2	3	4	5	NA	UNK
N2. Project Accounting Requirements	1	2	3	4	5	NA	UNK
N3. Risk Analysis	Yes		No			NA	UNK
P. Project Execution Plan	**(1) Complete <---------->Poor (5)**						
P1. Owner Approval Requirements	1	2	3	4	5	NA	UNK
P2. Engineering/Construction Plan & Approach	1	2	3	4	5	NA	UNK
P3. Shut Down/Turn-Around Requirements	Yes		No			NA	UNK
P4. Pre-Commissioned Turnover Sequence Requirements	1	2	3	4	5	NA	UNK
P5. Startup Requirements	1	2	3	4	5	NA	UNK
P6. Training Requirements	1	2	3	4	5	NA	UNK

Appendix B: Weights of Action Items for Project Management Attributes

FEP

Question	Weight	Choice						
		1	2	3	4	5	6	7
Select a score below that best describes the skill and experience of the Front End Planning team	0.735	0.00	0.17	0.33	0.50	0.67	0.83	1.00
Select a score below that best describes the authority and representation of the Front End Planning team.	0.735	0.00	0.17	0.33	0.50	0.67	0.83	1.00
In your opinion, how well defined were the roles and responsibilities of the Front End Planning Team members?	0.441	0.00	0.17	0.33	0.50	0.67	0.83	1.00
How would you assess the effectiveness of communication among the Front End Planning Team members?	0.441	0.00	0.17	0.33	0.50	0.67	0.83	1.00
Please assess the quality and completeness of the Front End Planning documentation?	0.735	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree		
"The owner's objectives, needs and expectations were clearly communicated to the Front End Planning Team."	0.735	1.00	0.75	0.50	0.25	0.00		
"The Front End Planning Team was well aligned in terms of the owner's objectives, needs and expectations."	0.735	1.00	0.75	0.50	0.25	0.00		
		1	2	3	4	5	6	7
Select a score below that best describes the technology evaluation performed for this project during Front End Planning.	0.735	0.00	0.17	0.33	0.50	0.67	0.83	1.00
Please assess the Front End Planning evaluation of alternate siting locations.	0.294	0.00	0.17	0.33	0.50	0.67	0.83	1.00
Assess the risk analysis of project alternatives performed during Front End Planning.	0.735	0.00	0.17	0.33	0.50	0.67	0.83	1.00
To what extent were appropriate risk mitigation strategies identified and clarified during Front End Planning?	0.735	0.00	0.17	0.33	0.50	0.67	0.83	1.00
Please indicate how well all necessary regulatory permits were addressed during Front End Planning.	0.441	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		No	Yes					
Did you use the PDRI or similar instrument to measure the level of definition for this project?	0.735	0.00	1.00					
		1	2	3	4	5	6	7
Please assess the completeness of the final scope definition.	0.588	0.00	0.17	0.33	0.50	0.67	0.83	1.00
How well were the budget and schedule aligned with the final scope definition?	0.735	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		Very Significan	Significant	Not Much	Essentially Not			
How significant of a problem was the inability of important team members to devote sufficient time to FEP?	0.441	0.00	0.33	0.67	1.00			

Alignment

Question	Weight	Choice						
		Excellent	Very Good	Fair	Poor			
How would you evaluate the effectiveness of the Front End Planning Team leadership for aligning team members to meet project objectives?	0.122	1.00	0.67	0.33	0.00			
		1	2	3	4	5	6	7
How well were the project goals and objectives defined during Front End Planning?	0.122	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree		
The project priorities in terms of cost, schedule and quality were clearly communicated.	0.122	1.00	0.75	0.50	0.25	0.00		
*The Front End Planning team culture fostered trust, honesty and open communication.	0.073	1.00	0.75	0.50	0.25	0.00		
*Team meetings were effective for gaining alignment on project objectives.	0.073	1.00	0.75	0.50	0.25	0.00		
		Always	Mostly	Some Times	Rarely	Never		
To what extent was communication in the Front End Planning process two-way communication?	0.073	1.00	0.75	0.50	0.25	0.00		
		1	2	3	4	5	6	7
How clearly was the project operations and maintenance philosophy communicated?	0.122	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		No	Yes					
Was there a reward/recognition system used during Front End Planning to promote team alignment?	0.049	0.00	1.00					
		Directly	Loosely	No				
To what extent was the reward/recognition system tied into the overall project objectives and priorities?	0.049	1.00	0.50	0.00				
		All	Most	Selective				
Were all members of the Front End Planning team and relevant internal groups and contractors included in the reward/recognition system?	0.024	1.00	0.50	0.00				
		No	Yes					
Did the Front End Planning Team use the Alignment Thermometer to evaluate team alignment?	0.049	0.00	1.00					
		1	2	3	4	5	6	7
How effective/helpful the use of the Alignment Thermometer was for evaluating and improving team alignment?	0.024	0.00	0.17	0.33	0.50	0.67	0.83	1.00
How effective were any planning tools that were used for promoting alignment (such as checklists, simulations, software programs, work flow diagrams for planning, developing, controlling and managing projects, etc.)?	0.098	0.00	0.17	0.33	0.50	0.67	0.83	1.00

Partnering - 1

Question	Weight	Choice				
		Very Committed	Somewhat Committed	Not Very Committed	Not at all Committed	
How would you describe your company's overall commitment to partnering?	0.046	1.00	0.67	0.33	0.00	
		Long History	Most Projects	Occarionally	Rarely	Not Use
Please indicate below how you would characterize your company's experience with using partnering.	0.046	1.00	0.75	0.50	0.25	0.00
		No	Yes			
Did you have a partnering agreement on this project with the primary contractor/owner?	0.046	0.00	1.00			
Was the primary contractor/owner on this project an organization with whom you have had an existing partnering relationship	0.046	0.00	1.00			
		<1 yr	1-2 yrs	2-5 yrs	5-10 yrs	>10 yrs
How long have you worked in a partnering relationship with this owner/ contractor?	0.031	0.00	0.25	0.50	0.75	1.00
		Very Supportive	Generally Supportive	Barrier		
Did the terms of the contract support/facilitate the partnering relationship?	0.077	1.00	0.50	0.00		
		No	Yes			
Was there a partnering agreement explicitly in the contract or referenced by the contract for this project?	0.046	0.00	1.00			
Please check the elements included in the partnering agreement?	0.046	Unchecked	Checked			
A mission statement for the partnering relationship		0.00	0.14			
Operating principles for the relationship		0.00	0.14			
Specification of expectations of the relationship		0.00	0.14			
Goals and objectives for the relationship		0.00	0.14			
Measures of success by which the services to be provided are judged		0.00	0.14			
Sharing of business plans and other key business information		0.00	0.14			
Incentive provisions to reinforce partnering		0.00	0.14			

Partnering - 2

Question	Weight	Choice						
		Jointly	Not Jointly	No plan				
Was there a jointly developed partnering implementation plan that was applied to this project?	0.077	1.00	0.50	0.00				
		Extensive	Moderate	Minimal	No effort	No Need		
Indicate the extent of education and training on this project that focused on how partnering works and its benefits.	0.046	1.00	0.67	0.33	0.00	1.00		
		Full time	Part time	No				
Was there a partnering champion or sponsor who was responsible for supporting the partnering relationship?	0.062	1.00	0.50	0.00				
		Outside Facilitator	In-House Facilitator	No Facilitator	No Workshop			
Was there an initial kick off partnering workshop conducted?	0.046	1.00	0.67	0.33	0.00			
		Routinely	Occasionaly	Not too often	Not at all			
To what extent were social gatherings and other perks provided to the partnering participants?	0.031	1.00	0.67	0.33	0.00			
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree		
Team members felt free to offer suggestions openly.	0.062	1.00	0.75	0.50	0.25	0.00		
The partnering relationship facilitated/promoted innovation	0.062	1.00	0.75	0.50	0.25	0.00		
Decision making on the partnering team was collaborative.	0.062	1.00	0.75	0.50	0.25	0.00		
		No	Yes					
Was there a method for measuring and evaluating the effectiveness of the work processes of the partnering team?	0.046	0.00	1.00					
		1	2	3	4	5	6	7
Please indicate how useful this evaluation was for implementing improvements to the partnering process on this project.	0.062	0.00	0.17	0.33	0.50	0.67	0.83	1.00
Please indicate the extent to which the partnering relationship was characterized by a shared vision, shared culture, and trust.	0.062	0.00	0.17	0.33	0.50	0.67	0.83	1.00

Team Building

Question	Weight	Choice				
		Very Committed	Somewhat Committed	Not Very Committed	Not at all Committed	
Please describe your company's commitment to formal team building.	0.172	1.00	0.67	0.33	0.00	
		No	Yes			
Was a formal team building program used on this project?	0.172	0.00	1.00			
		FEP	Engineering	Constructi on	Other	
What was the earliest point in this project when the formal team building program was implemented?	0.034	1.00	0.67	0.33	0.00	
		Extensive	Sufficient	Superficial	No Workshop	
Some team building programs use one or more retreat type workshops where shared goals are developed and essential decision making and dispute resolution procedures are worked out.	0.103	1.00	0.67	0.33	0.00	
		Yes, and Effective	Yes, not Effective	In-House Facilitator	No Facilitator	
Was an outside consultant or facilitator used as part of the team building workshop?	0.103	1.00	0.67	0.33	0.00	
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The relevant stakeholders were represented at the team building workshop(s).	0.172	1.00	0.75	0.50	0.25	0.00
A sufficient number of follow up team building meetings were held to reinforce team building concepts and integrate new team members.	0.138	1.00	0.75	0.50	0.25	0.00
		Reguarly	Sporadic	Not focus	No jobsite Meeting	
Were there job site meetings that focused at least in part on team building?	0.103	1.00	0.67	0.33	0.00	

PDCS

Question	Weight	Choice						
		No	Yes					
Did you consider alternative project delivery methods for this project?	0.106	0.00	1.00					
		1 - No	2	3	4 - Partial	5	6	7 - Systematic
To what extent did the business planning stage of this project include a review of the business objectives and ranking of the relative importance of these objectives?	0.085	0.00	0.17	0.33	0.50	0.67	0.83	1.00
To what extent did the business planning stage include a systematic evaluation of strengths and weaknesses of these alternative project delivery methods?	0.106	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		No	Yes					
Were the project delivery methods ranked or prioritized in terms of suitability?	0.064	0.00	1.00					
Did you consider alternative contract types for this project?	0.106	0.00	1.00					
Were alternative contract types considered for this project for the primary contractor?	0.085	0.00	1.00					
		1 - No	2	3	4 - Partial	5	6	7 - Systematic
To what extent did the business planning stage include a systematic evaluation of strengths and weaknesses of alternative contract types for the primary contractor?	0.106	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		No	Yes					
Were the different project contract types ranked or prioritized in terms of suitability?	0.064	0.00	1.00					
Did you use a tool for assisting with the determination of the project delivery method and contract type for this project?	0.064	0.00	1.00					
		Different	Same					
Looking back on this project, knowing what you know now (and absent any statutory restrictions), what do you think would have been the optimal project delivery method for this project?	0.106	0.00	1.00					
what do you think would have been the optimal contract type for.. Engineering or design		0.00	0.33					
what do you think would have been the optimal contract type for.. Procurement		0.00	0.33					
what do you think would have been the optimal contract type for.. Construction and startup		0.00	0.33					

Constructability - 1

Question	Weight	Choice				
		No	Casually	Formally	Stand	
Select the description below that best describes your corporate constructability program.	0.077	0.00	0.33	0.67	1.00	
		None	Word of Mouth	Individual Document ation	System	Formal, all levels
How would you characterize your company's tracking of constructability lessons learned?	0.058	0.00	0.25	0.50	0.75	1.00
		None	Part time	Full or part time	Full time	
Which statement best describes the role of a constructability coordinator	0.096	0.00	0.33	0.67	1.00	
		Uncheak	Check			
Indicate the project phases in which constructability concepts and principles were systematically applied: early fep	0.096	0.00	0.40			
Indicate the project phases in which constructability concepts and principles were systematically applied: late fep		0.00	0.30			
Indicate the project phases in which constructability concepts and principles were systematically applied:early in detail eng		0.00	0.15			
Indicate the project phases in which constructability concepts and principles were systematically applied: late in detail eng		0.00	0.10			
Indicate the project phases in which constructability concepts and principles were systematically applied: beg. Of construction		0.00	0.05			
Indicate the project phases in which constructability concepts and principles were systematically applied: not system. Applied		0.00	0.00			
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Appropriate, knowledgeable construction personnel were able to effectively interface with appropriate design personnel (design personnel with authority over design issues).	0.096	1.00	0.75	0.50	0.25	0.00

Constructability - 2

Question	Weight	Choice						
		No effort	Mimimum	Moderate	Substantial			
Which of the following best describes how constructability principles were communicated on this project?	0.058	0.00	0.33	0.67	1.00			
		No	Yes					
Was there a formal documented constructability plan for this project?	0.077	0.00	1.00					
		1 - No	2	3	4 - Partial	5	6	7 - Fully
Was the constructability plan integrated into the project execution plan?	0.096	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		No Construct-ability	Minor Barriers	Several Significant Barriers	Many Significant Barrier			
Which of the following best describes how barriers to constructability were addressed on this project.	0.058	0.00	1.00	0.67	0.33			
		Not at all	Rarely	Sometime	Routinely			
To what extent did the constructability team incorporate relevant information from the lessons learned data base into the project execution	0.038	0.00	0.33	0.67	1.00			
		Essentially no	Modest	Adequate	Very well			
How would you characterize the funding for constructability on this project?	0.096	0.00	0.33	0.67	1.00			
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree		
The project constructability efforts were periodically evaluated, updated and improved.	0.058	1.00	0.75	0.50	0.25	0.00		
		1 - No	2	3	4 - Partial	5	6	7 - Fully
To what extent did the engineering deliverables reflect the recommendations for constructability from construction personnel?	0.096	0.00	0.17	0.33	0.50	0.67	0.83	1.00

Project Risk Assessment - 1

Question	Weight	Choice		
How would you describe the risk assessment(s) conducted on this project?	0.071	No	Informal	Formal
		0.00	0.50	1.00

Question	Weight	Feasibility	Project Definition	Decision to Proceed	Engineering	Procurement	Construction	Startup	Other	No
At what point during this project was the first formal risk assessment conducted	0.089	1.00	0.90	0.80	0.60	0.40	0.20	0.00	0.00	0.00

Question	Weight	Regularly	Quarterly	Less frequently than quarterly	Sporadically	Not really updated
How frequently was the risk assessment updated?	0.089	1.00	0.75	0.50	0.25	0.00

Question	Weight	No	Very Involved	Limited Role
Was an outside facilitator used on this project to assist with risk assessment?	0.054	0.00	1.00	0.50

Question	Weight	1 - No	2	3	4 - Partial	5	6	7 - Fully
To what extent were all of the necessary, relevant project team members involved in the risk assessment process?	0.089	0.00	0.17	0.33	0.50	0.67	0.83	1.00

Question	Weight	Uncheck	Check
Which of the following elements: Ranking of key risk elements by likelihood of occurrence	0.089		
Ranking of key risk elements by LIKELIHOOD OF OCCURRENCE		0.00	0.25
Ranking of key risk elements by relative impact		0.00	0.25
Identifying most significant risks through analysis that combined likelihood of occurrence and relative IMPACT		0.00	0.25
Identification of mitigation strategies for most significant risks		0.00	0.25

Project Risk Assessment - 2

Question	Weight	Choice						
		Thorough	Partially	Not well	Not at all			
How well documented was the risk assessment process for this	0.054	1.00	0.67	0.33	0.00			
		No	Itemized	General documen				
Was a risk mitigation plan developed?	0.089	0.00	1.00	0.50				
Which of the following were included in the risk mitigation plan	0.089	Unchea	Check					
The likelihood of occurrence of the risk event		0.00	0.17					
The specific impact (cost, schedule, quality, scope, etc.) of the risk		0.00	0.17					
Relative cost of the mitigation action		0.00	0.17					
Identification of the mitigation strategy		0.00	0.17					
Probability of success of the mitigation action		0.00	0.17					
Responsible party and time line for mitigation		0.00	0.17					
		Regularly	Quarterly	Less frequently than quarterly	Sporadically	Not really updated		
To what extent was the risk mitigation plan updated?	0.089	1.00	0.75	0.50	0.25	0.00		
		1 - No	2	3	4 - Partial	5	6	7 - Fully
To what extent was the risk mitigation plan implemented?	0.089	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		No	Partially	Fully				
Were the mitigation costs and contingency added to the authorized project budget as a result of the risk assessment process?	0.054	0.00	0.50	1.00				
Were the schedule impacts of mitigation added to the baseline project schedule as a result of the risk assessment process?	0.054	0.00	0.50	1.00				

Change Management - 1

Question	Weight	Choice						
		No	Yes					
Was there a formal (documented in writing) change management process for this project?	0.104	0.00	1.00					
		1 - Not clear at all	2	3	4 - Moderate clear	5	6	7 - very clear
How clearly was the change management process specified in the project contract?	0.104	0.00	0.17	0.33	0.50	0.67	0.83	1.00
How well would you say key project personnel (both owners and contractors) understood the change management process?	0.104	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		No	Yes					
Would you say that changes on this project generally were proactively managed? By proactively, we mean timely, hands-on,	0.104	0.00	1.00					
		1 - Not clear at all	2	3	4 - Moderate clear	5	6	7 - very clear
To what extent was the change management process used to proactively manage changes on this project? detailed	0.083	0.00	0.17	0.33	0.50	0.67	0.83	1.00
To what extent was the change management process used to proactively manage changes on this project? construction/startup.	0.083	0.00	0.17	0.33	0.50	0.67	0.83	1.00

Change Management – 2

Question	Weight	Choice						
		1 - not at all	2	3	4 - Sometimes	5	6	7 - Always
To what extent were major changes (i.e., those that exceeded a specified project threshold) required to go through a formal change justification procedure?	0.083	0.00	0.17	0.33	0.50	0.67	0.83	1.00
Was owner authorization required before implementation of major changes?	0.063	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		1 - Poorly	2	3	4 - Variable	5	6	7 - Routinely
How well do you think change information was communicated to key project participants?	0.083	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		1 - not at all	2	3	4 - Moderately	5	6	7 - Fully
To what extent were areas susceptible to change identified and evaluated for risk during review of the project design basis?	0.083	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		1 - not at all	2	3	4 - Sometimes	5	6	7 - Always
Did project personnel negotiate and authorize change orders on this project in a timely manner?	0.104	0.00	0.17	0.33	0.50	0.67	0.83	1.00

Zero Accident Technique – 1

Question	Weight	Choice						
		No	Yes					
Was there a written site specific safety plan for this project?	0.093	0.00	1.00					
		No site safety supervisor	Part time	Full time				
Which of the following best describes the time commitment of the site safety supervisor for this project?	0.093	0.00	0.50	1.00				
		Over 200	150-200	70-150	20-70	1-20		
Overall how many workers per safety person were typically (i.e., in terms of the average workforce) on site?	0.056	0.00	0.25	0.50	0.75	1.00		
		1 - not at all	2	3	4 - Cursory Orientation	5	6	7 - Extensive Orientatio
How extensive was the job-specific safety orientation conducted for new contractor and subcontractor employees?	0.093	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		None	< 1 hrs/mo	1-5 hrs/mo	5-8	>8 hrs/mo		
On average how much ongoing formal safety training did workers receive each month?	0.056	0.00	0.25	0.50	0.75	1.00		
		2+/day	Daily	Several/w	Weekly	Monthly	None	
On average, how often were safety toolbox meetings held?	0.093	1.00	0.80	0.60	0.40	0.20	0.00	

Zero Accident Technique – 2

Question	Weight	Choice							
		Annually	Quarterly	Monthly	Biweekly	Weekly	Never		
How often were safety audits performed by corporate safety personnel	0.093	0.00	0.20	0.40	0.60	0.80	1.00		
		Never	Occasionally	Usually	Always				
To what extent were pre-employment substance abuse tests conducted for contractor employees?	0.056	0.00	0.33	0.67	1.00				
		Not at all	Once a year	Twice a year	Quarterly	Monthly			
How frequently were contractor employees randomly screened for alcohol and drugs?	0.056	0.00	0.25	0.50	0.75	1.00			
		1 - Never	2	3	4 - Sometime	5	6	7 - Always	None Occurred
How often were near-misses formally (i.e., written documentation) investigated?	0.093	0.00	0.17	0.33	0.50	0.67	0.83	1.00	1.00
		1 - not at all	2	3	4 - Moderately	5	6	7 - Extensively	
To what extent were safety incentives used that were based upon zero injury objectives?	0.056	0.00	0.17	0.33	0.50	0.67	0.83	1.00	
to what extent was safety performance utilized as a criterion for contractor /subcontractor selection?	0.074	0.00	0.17	0.33	0.50	0.67	0.83	1.00	
To what extent were safety risks systematically identified in the pre-construction phases of this project?	0.093	0.00	0.17	0.33	0.50	0.67	0.83	1.00	

Planning for Startup – 1

Question	Weight	Choice								
		1 - not at all	2	3	4 - Moderate	5	6	7 - Very well		
How well were the startup objectives defined?	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
Please indicate how well startup objectives were communicated to the relevant project team members.	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
		1 - not at all	2	3	4 - Modest	5	6	7 - fully resource		
How would you characterize the allocation of resources to planning for	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
		1 - not at all clear	2	3	4 - Moderately clear	5	6	7 - Very clear		
How clearly were the startup team's roles and responsibilities identified?	0.048	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
How clearly were the startup teams roles and responsibilities communicated to all project stakeholders?	0.048	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
		1 - not at all	2	3	4 - Partially	5	6	7 - Very extensively		
To what extent was a formal startup execution plan developed?	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
To what extent was a formal startup execution plan implemented?	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
		Routinely	Occasionally	Not updated	No change					
Was the startup execution plan kept current?	0.048	1.00	0.50	0.00	1.00					
		1 - not at all	2	3	4 - Partially	5	6	7 - Very extensively		
How well were major startup systems and startup sequences identified during front end engineering?	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
To what extent was the startup schedule driven by the startup sequence	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
		1 - not at all incorporated	2	3	4 - Partially incorporated	5	6	7 - full incorporated		
To what extent were startup needs incorporated into the procurement requirements?	0.036	0.00	0.17	0.33	0.50	0.67	0.83	1.00		
		Early FEP	Middle FEP	Late FEP	Early ENGR	Mid ENGR	Late ENGR	Early Const.	Mid Const.	Late Const.
Please indicate the earliest time period of the first project meeting that explicitly and systematically focused on planning for startup.	0.036	1.00	0.88	0.75	0.63	0.50	0.38	0.25	0.13	0.00
Please indicate when the startup plan was initially developed?	0.036	1.00	0.88	0.75	0.63	0.50	0.38	0.25	0.13	0.00
Please indicate when the startup team was initially assembled?	0.036	1.00	0.88	0.75	0.63	0.50	0.38	0.25	0.13	0.00

Planning for Startup – 2

Question	Weight	Choice						
		1 - not at all	2	3	4 - Periodically	5	6	7 - Continuously
How often were startup risks assessed?	0.036	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		1 - no formal training	2	3	4 - Moderate	5	6	7 - Extensive formal training
How would you characterize the extent of formal operator/maintenance	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		Unchea	Check					
Were any tools or checklists used to assist with startup planning?tool that helped us develop the startup plan	0.048	0.00	0.50					
Were any tools or checklists used to assist with startup planning?a tool to evaluate the extent of startup planning		0.00	0.50					
Were any tools or checklists used to assist with startup planning?No, we did not use any tools or checklists for startup planning		0.00	0.00					
Were any tools or checklists used to assist with startup planning? Don't								
		1 - not at all adequate	2	3	4 - Moderately adequate	5	6	7 - excellent
How would you characterize the system turnover plan?	0.048	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		1 - not at all involved	2	3	4 - Moderately Involved	5	6	7 - Intensively Involved
How involved was the startup team in developing startup procedures?	0.060	0.00	0.17	0.33	0.50	0.67	0.83	1.00
		1 - Poorly	2	3	4 - Moderately well	5	6	7 - very well
How well were Process Safety Management procedures communicated to the operations and maintenance personnel?	0.036	0.00	0.17	0.33	0.50	0.67	0.83	1.00

Appendix C: Contingency Table Analysis Results

Owner Projects

Contractor Projects

Contingency Table Analysis Results for Cost Growth Performance of Owner Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.7	8.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	40 (52.6%)	11 (91.7%)	51	0.27	0.011 **	0.012 **
Worse	Cost Growth>0	36 (47.4%)	1 (8.3%)	37			
Total		76	12	88			

FEP		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.7	7.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	33 (41.8%)	39 (75.0%)	72	0.33	0.000 ***	0.000 ***
Worse	Cost Growth>0	46 (58.2%)	13 (25.0%)	59			
Total		79	52	131			

Alignment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.7	5.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	11 (29.7%)	60 (64.5%)	71	0.32	0.000 ***	0.000 ***
Worse	Cost Growth>0	26 (70.3%)	33 (35.5%)	59			
Total		37	93	130			

Partnering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.3	6.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	48 (49.0%)	20 (76.9%)	68	0.23	0.011 **	0.014 **
Worse	Cost Growth>0	50 (51.0%)	6 (23.1%)	56			
Total		98	26	124			

Team Building		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~9.3	9.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	71 (55.0%)	4 (66.7%)	75	0.05	0.575	0.692
Worse	Cost Growth>0	58 (45.0%)	2 (33.3%)	60			
Total		129	6	135			

Change Management		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.1	8.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	15 (38.5%)	60 (63.8%)	75	0.23	0.007 ***	0.012 **
Worse	Cost Growth>0	24 (61.5%)	34 (36.2%)	58			
Total		39	94	133			

Contingency Table Analysis Results for Cost Growth Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDCS		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.3	8.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	52 (54.7%)	13 (81.3%)	65	0.19	0.046 **	0.057 *
Worse	Cost Growth>0	43 (45.3%)	3 (18.8%)	46			
Total		95	16	111			

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8	8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	66 (54.1%)	4 (80.0%)	70	0.10	0.254	0.378
Worse	Cost Growth>0	56 (45.9%)	1 (20.0%)	57			
Total		122	5	127			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	62 (54.4%)	6 (66.7%)	68	0.06	0.476	0.730
Worse	Cost Growth>0	52 (45.6%)	3 (33.3%)	55			
Total		114	9	123			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.6	5.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	5 (29.4%)	53 (57.6%)	58	0.02	0.032 **	0.038 **
Worse	Cost Growth>0	12 (70.6%)	39 (42.4%)	51			
Total		17	92	109			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.7	6.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	24 (55.8%)	26 (50.0%)	50	0.21	0.572	0.680
Worse	Cost Growth>0	19 (44.2%)	26 (50.0%)	45			
Total		43	52	95			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.3	4.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (18.2%)	68 (70.8%)	70	0.34	0.001 ***	0.001 ***
Worse	Cost Growth>0	9 (81.8%)	28 (29.2%)	37			
Total		11	96	107			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.2	7.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	29 (50.0%)	40 (75.5%)	69	0.26	0.006 ***	0.007 ***
Worse	Cost Growth>0	29 (50.0%)	13 (24.5%)	42			
Total		58	53	111			

Contingency Table Analysis Results for Cost Growth Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Percent Design at AFE		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.1	4.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	31 (54.4%)	22 (84.6%)	53	0.29	0.008 ***	0.013 **
Worse	Cost Growth>0	26 (45.6%)	4 (15.4%)	30			
Total		57	26	83			

Percent Design prior to Constr.		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~3.2	3.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	8 (40.0%)	43 (71.7%)	51	0.29	0.011 **	0.016 **
Worse	Cost Growth>0	12 (60.0%)	17 (28.3%)	29			
Total		20	60	80			

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.2	7.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	11 (39.3%)	26 (61.9%)	37	0.22	0.063 *	0.088 *
Worse	Cost Growth>0	17 (60.7%)	16 (38.1%)	33			
Total		28	42	70			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.1	6.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (37.5%)	17 (42.5%)	20	0.04	0.793	1.000
Worse	Cost Growth>0	5 (62.5%)	23 (57.5%)	28			
Total		8	40	48			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		No	Yes	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	45 (59.2%)	25 (54.3%)	70	0.05	0.599	0.706
Worse	Cost Growth>0	31 (40.8%)	21 (45.7%)	52			
Total		76	46	122			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0.1	0.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	43 (58.9%)	25 (59.5%)	68	0.01	0.948	1.000
Worse	Cost Growth>0	30 (41.1%)	17 (40.5%)	47			
Total		73	42	115			

Contingency Table Analysis Results for Schedule Growth Performance of Owner Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level		
Performance		0~6.7	6.7~10	Total
Better	Cost Growth<=0	2 (18.2%)	23 (36.5%)	25
Worse	Cost Growth>0	9 (81.8%)	40 (63.5%)	49
Total		11	63	74

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.14	0.236	0.314

FEP		Implementation Level		
Performance		0~7.5	7.5~10	Total
Better	Cost Growth<=0	14 (25.0%)	21 (45.7%)	35
Worse	Cost Growth>0	42 (75.0%)	25 (54.3%)	67
Total		56	46	102

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.22	0.029 **	0.037 **

Alignment		Implementation Level		
Performance		0~6	6~10	Total
Better	Cost Growth<=0	8 (22.9%)	28 (42.4%)	36
Worse	Cost Growth>0	27 (77.1%)	38 (57.6%)	65
Total		35	66	101

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.19	0.051 *	0.080 *

Partnering		Implementation Level		
Performance		0~6	6~10	Total
Better	Cost Growth<=0	21 (30.0%)	14 (51.9%)	35
Worse	Cost Growth>0	49 (70.0%)	13 (48.1%)	62
Total		70	27	97

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.20	0.045 **	0.060 *

Team Building		Implementation Level		
Performance		0~6.7	6.7~10	Total
Better	Cost Growth<=0	22 (28.9%)	15 (55.6%)	37
Worse	Cost Growth>0	54 (71.1%)	12 (44.4%)	66
Total		76	27	103

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.24	0.013 **	0.019 **

Change Management		Implementation Level		
Performance		0~6.2	6.2~10	Total
Better	Cost Growth<=0	1 (7.1%)	35 (39.8%)	36
Worse	Cost Growth>0	13 (92.9%)	53 (60.2%)	66
Total		14	88	102

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.23	0.018 **	0.017 **

Contingency Table Analysis Results for Schedule Growth Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDCS		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.2	6.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	13 (27.7%)	18 (50.0%)	31	0.23	0.037 **	0.043 **
Worse	Cost Growth>0	34 (72.3%)	18 (50.0%)	52			
Total		47	36	83			

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.8	7.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	30 (32.6%)	4 (57.1%)	34	0.13	0.188	0.228
Worse	Cost Growth>0	62 (67.4%)	3 (42.9%)	65			
Total		92	7	99			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.4	4.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	7 (18.9%)	26 (44.1%)	33	0.26	0.012 **	0.015 **
Worse	Cost Growth>0	30 (81.1%)	33 (55.9%)	63			
Total		37	59	96			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7	7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (14.3%)	28 (45.9%)	32	0.02	0.004 ***	0.004 ***
Worse	Cost Growth>0	24 (85.7%)	33 (54.1%)	57			
Total		28	61	89			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.4	5.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (28.6%)	30 (37.5%)	32	0.31	0.639	1.000
Worse	Cost Growth>0	5 (71.4%)	50 (62.5%)	55			
Total		7	80	87			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.2	7.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	12 (30.0%)	17 (48.6%)	29	0.19	0.099 *	0.153
Worse	Cost Growth>0	28 (70.0%)	18 (51.4%)	46			
Total		40	35	75			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (17.4%)	26 (46.4%)	30	0.27	0.016 **	0.021 **
Worse	Cost Growth>0	19 (82.6%)	30 (53.6%)	49			
Total		23	56	79			

Contingency Table Analysis Results for Schedule Growth Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Percent Design at AFE		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0.8	0.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (23.1%)	24 (40.7%)	27	0.14	0.235	0.346
Worse	Cost Growth>0	10 (76.9%)	35 (59.3%)	45			
Total		13	59	72			

Percent Design prior to Constr.		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~3.2	3.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (16.7%)	22 (42.3%)	25	0.23	0.050 **	0.085 *
Worse	Cost Growth>0	15 (83.3%)	30 (57.7%)	45			
Total		18	52	70			

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (21.1%)	17 (40.5%)	21	0.19	0.139	0.160
Worse	Cost Growth>0	15 (78.9%)	25 (59.5%)	40			
Total		19	42	61			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.1	6.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (16.7%)	11 (36.7%)	12	0.16	0.343	0.640
Worse	Cost Growth>0	5 (83.3%)	19 (63.3%)	24			
Total		6	30	36			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		No	Yes	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	18 (32.7%)	15 (42.9%)	33	0.10	0.331	0.374
Worse	Cost Growth>0	37 (67.3%)	20 (57.1%)	57			
Total		55	35	90			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~3.1	3.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	34 (37.8%)	3 (60.0%)	37	0.10	0.321	0.374
Worse	Cost Growth>0	56 (62.2%)	2 (40.0%)	58			
Total		90	5	95			

Contingency Table Analysis Results for Safety Performance of Owner Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8	8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	18 (42.9%)	19 (61.3%)	37	0.18	0.119	0.157
Worse	Cost Growth>0	24 (57.1%)	12 (38.7%)	36			
Total		42	31	73			

FEP		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~9.1	9.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	49 (48.5%)	9 (90.0%)	58	0.24	0.012 **	0.017 **
Worse	Cost Growth>0	52 (51.5%)	1 (10.0%)	53			
Total		101	10	111			

Alignment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.2	7.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	24 (40.0%)	31 (63.3%)	55	0.23	0.016 **	0.021 **
Worse	Cost Growth>0	36 (60.0%)	18 (36.7%)	54			
Total		60	49	109			

Partnering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7	7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	43 (47.8%)	11 (73.3%)	54	0.18	0.067 *	0.094 *
Worse	Cost Growth>0	47 (52.2%)	4 (26.7%)	51			
Total		90	15	105			

Team Building		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~9.3	9.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	56 (50.9%)	4 (80.0%)	60	0.12	0.203	0.366
Worse	Cost Growth>0	54 (49.1%)	1 (20.0%)	55			
Total		110	5	115			

Change mgt		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	28 (46.7%)	31 (58.5%)	59	0.12	0.209	0.259
Worse	Cost Growth>0	32 (53.3%)	22 (41.5%)	54			
Total		60	53	113			

Contingency Table Analysis Results for Safety Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDCS		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.8	8.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	47 (48.5%)	8 (80.0%)	55	0.18	0.057 *	0.094 *
Worse	Cost Growth>0	50 (51.5%)	2 (20.0%)	52			
Total		97	10	107			

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.8	7.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	52 (51.0%)	7 (87.5%)	59	0.19	0.046 **	0.066 *
Worse	Cost Growth>0	50 (49.0%)	1 (12.5%)	51			
Total		102	8	110			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.4	7.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	41 (47.1%)	15 (75.0%)	56	0.22	0.024 **	0.028 **
Worse	Cost Growth>0	46 (52.9%)	5 (25.0%)	51			
Total		87	20	107			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.9	6.9~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	10 (34.5%)	40 (62.5%)	50	0.02	0.012 **	0.022 **
Worse	Cost Growth>0	19 (65.5%)	24 (37.5%)	43			
Total		29	64	93			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.4	6.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	10 (34.5%)	39 (61.9%)	49	0.26	0.014 **	0.024 **
Worse	Cost Growth>0	19 (65.5%)	24 (38.1%)	43			
Total		29	63	92			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	41 (48.2%)	11 (78.6%)	52	0.21	0.035 **	0.045 **
Worse	Cost Growth>0	44 (51.8%)	3 (21.4%)	47			
Total		85	14	99			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.3	4.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (33.3%)	51 (54.8%)	55	0.14	0.160	0.222
Worse	Cost Growth>0	8 (66.7%)	42 (45.2%)	50			
Total		12	93	105			

Contingency Table Analysis Results for Safety Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Percent Design at AFE		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.1	4.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	20 (47.6%)	11 (50.0%)	31	0.02	0.856	1.000
Worse	Cost Growth>0	22 (52.4%)	11 (50.0%)	33			
Total		42	22	64			

Percent Design prior to Constr.		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~2.6	2.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (33.3%)	30 (53.6%)	32	0.12	0.346	0.418
Worse	Cost Growth>0	4 (66.7%)	26 (46.4%)	30			
Total		6	56	62			

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	14 (46.7%)	16 (66.7%)	30	0.20	0.142	0.175
Worse	Cost Growth>0	16 (53.3%)	8 (33.3%)	24			
Total		30	24	54			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.1	8.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	10 (52.6%)	17 (60.7%)	27	0.08	0.582	0.764
Worse	Cost Growth>0	9 (47.4%)	11 (39.3%)	20			
Total		19	28	47			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		No	Yes	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	36 (48.6%)	26 (57.8%)	62	0.09	0.334	0.351
Worse	Cost Growth>0	38 (51.4%)	19 (42.2%)	57			
Total		74	45	119			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~2.1	2.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	36 (43.9%)	7 (77.8%)	43	0.20	0.053 *	0.079 *
Worse	Cost Growth>0	46 (56.1%)	2 (22.2%)	48			
Total		82	9	91			

Contingency Table Analysis Results for Quality Performance of Owner Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level		
Performance		0~7.9	7.9~10	Total
Better	Cost Growth<=0	6 (17.1%)	20 (52.6%)	26
Worse	Cost Growth>0	29 (82.9%)	18 (47.4%)	47
Total		35	38	73

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.37	0.002 ***	0.003 ***

FEP		Implementation Level		
Performance		0~9.1	9.1~10	Total
Better	Cost Growth<=0	31 (30.4%)	9 (90.0%)	40
Worse	Cost Growth>0	71 (69.6%)	1 (10.0%)	72
Total		102	10	112

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.35	0.000 ***	0.000 ***

Alignment		Implementation Level		
Performance		0~8.6	8.6~10	Total
Better	Cost Growth<=0	27 (27.6%)	11 (91.7%)	38
Worse	Cost Growth>0	71 (72.4%)	1 (8.3%)	72
Total		98	12	110

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.42	0.000 ***	0.000 ***

Partnering		Implementation Level		
Performance		0~7.3	7.3~10	Total
Better	Cost Growth<=0	30 (31.6%)	6 (50.0%)	36
Worse	Cost Growth>0	65 (68.4%)	6 (50.0%)	71
Total		95	12	107

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.12	0.203	0.213

Team Building		Implementation Level		
Performance		0~9.3	9.3~10	Total
Better	Cost Growth<=0	36 (32.1%)	3 (60.0%)	39
Worse	Cost Growth>0	76 (67.9%)	2 (40.0%)	78
Total		112	5	117

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.12	0.196	0.332

Change mgt		Implementation Level		
Performance		0~6.5	6.5~10	Total
Better	Cost Growth<=0	3 (13.6%)	36 (38.7%)	39
Worse	Cost Growth>0	19 (86.4%)	57 (61.3%)	76
Total		22	93	115

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.21	0.025 **	0.026 **

Contingency Table Analysis Results for Quality Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDCS		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~9.1	9.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	34 (33.0%)	3 (60.0%)	37	0.12	0.214	0.336
Worse	Cost Growth>0	69 (67.0%)	2 (40.0%)	71			
Total		103	5	108			

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~2.1	2.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (9.1%)	38 (38.0%)	39	0.18	0.052 *	0.093 *
Worse	Cost Growth>0	10 (90.9%)	62 (62.0%)	72			
Total		11	100	111			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.8	8.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	35 (33.7%)	3 (75.0%)	38	0.16	0.089 *	0.124
Worse	Cost Growth>0	69 (66.3%)	1 (25.0%)	70			
Total		104	4	108			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~9	9~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	21 (27.3%)	10 (62.5%)	31	0.02	0.012 **	0.022 **
Worse	Cost Growth>0	56 (72.7%)	6 (37.5%)	62			
Total		77	16	93			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.7	7.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	21 (35.0%)	17 (50.0%)	38	0.28	0.007 ***	0.010 ***
Worse	Cost Growth>0	39 (65.0%)	17 (50.0%)	56			
Total		60	34	94			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	26 (29.9%)	7 (50.0%)	33	0.15	0.136	0.217
Worse	Cost Growth>0	61 (70.1%)	7 (50.0%)	68			
Total		87	14	101			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	7 (25.0%)	31 (40.3%)	38	0.14	0.150	0.174
Worse	Cost Growth>0	21 (75.0%)	46 (59.7%)	67			
Total		28	77	105			

Contingency Table Analysis Results for Quality Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Percent Design at AFE		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~9.6	9.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	23 (37.7%)	3 (75.0%)	26	0.18	0.140	0.293
Worse	Cost Growth>0	38 (62.3%)	1 (25.0%)	39			
Total		61	4	65			

Percent Design prior to Constr.		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~3.2	3.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (18.8%)	22 (46.8%)	25	0.25	0.048 **	0.075 *
Worse	Cost Growth>0	13 (81.3%)	25 (53.2%)	38			
Total		16	47	63			

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	6 (19.4%)	11 (45.8%)	17	0.28	0.035 **	0.044 **
Worse	Cost Growth>0	25 (80.6%)	13 (54.2%)	38			
Total		31	24	55			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.1	8.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (10.5%)	10 (35.7%)	12	0.28	0.052 *	0.087 *
Worse	Cost Growth>0	17 (89.5%)	18 (64.3%)	35			
Total		19	28	47			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		No	Yes	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	27 (36.0%)	14 (30.4%)	41	0.06	0.530	0.559
Worse	Cost Growth>0	48 (64.0%)	32 (69.6%)	80			
Total		75	46	121			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~2.1	2.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	25 (29.8%)	6 (66.7%)	31	0.23	0.026 **	0.056 *
Worse	Cost Growth>0	59 (70.2%)	3 (33.3%)	62			
Total		84	9	93			

Contingency Table Analysis Results for Business Performance of Owner Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.3	8.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	22 (43.1%)	18 (81.8%)	40	0.36	0.002 ***	0.004 ***
Worse	Cost Growth>0	29 (56.9%)	4 (18.2%)	33			
Total		51	22	73			

FEP		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.1	8.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	33 (44.6%)	31 (86.1%)	64	0.39	0.000 ***	0.000 ***
Worse	Cost Growth>0	41 (55.4%)	5 (13.9%)	46			
Total		74	36	110			

Alignment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.6	7.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	32 (43.2%)	31 (88.6%)	63	0.43	0.000 ***	0.000 ***
Worse	Cost Growth>0	42 (56.8%)	4 (11.4%)	46			
Total		74	35	109			

Partnering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.3	7.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	49 (51.6%)	11 (91.7%)	60	0.25	0.008 ***	0.011 **
Worse	Cost Growth>0	46 (48.4%)	1 (8.3%)	47			
Total		95	12	107			

Team Building		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~9.3	9.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	61 (55.0%)	4 (80.0%)	65	0.10	0.270	0.383
Worse	Cost Growth>0	50 (45.0%)	1 (20.0%)	51			
Total		111	5	116			

Change mgt		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.1	6.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (22.2%)	60 (62.5%)	64	0.30	0.002 ***	0.002 ***
Worse	Cost Growth>0	14 (77.8%)	36 (37.5%)	50			
Total		18	96	114			

Contingency Table Analysis Results for Business Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDCS		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.9	8.9~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	56 (55.4%)	5 (83.3%)	61	0.13	0.180	0.234
Worse	Cost Growth>0	45 (44.6%)	1 (16.7%)	46			
Total		101	6	107			

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.9	7.9~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	61 (58.7%)	5 (83.3%)	66	0.11	0.230	0.399
Worse	Cost Growth>0	43 (41.3%)	1 (16.7%)	44			
Total		104	6	110			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~1.3	1.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	6 (33.3%)	55 (61.8%)	61	0.22	0.026 **	0.036 **
Worse	Cost Growth>0	12 (66.7%)	34 (38.2%)	46			
Total		18	89	107			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.3	8.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	26 (41.9%)	26 (83.9%)	52	0.02	0.000 ***	0.000 ***
Worse	Cost Growth>0	36 (58.1%)	5 (16.1%)	41			
Total		62	31	93			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.4	8.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	42 (56.0%)	12 (80.0%)	54	0.40	0.083 *	0.147
Worse	Cost Growth>0	33 (44.0%)	3 (20.0%)	36			
Total		75	15	90			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.3	4.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (18.2%)	54 (61.4%)	56	0.27	0.006 ***	0.009 ***
Worse	Cost Growth>0	9 (81.8%)	34 (38.6%)	43			
Total		11	88	99			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.2	7.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	30 (52.6%)	31 (67.4%)	61	0.15	0.130	0.160
Worse	Cost Growth>0	27 (47.4%)	15 (32.6%)	42			
Total		57	46	103			

Contingency Table Analysis Results for Business Performance of Owner Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Percent Design at AFE		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.1	5.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	23 (47.9%)	14 (87.5%)	37	0.35	0.005 ***	0.008 ***
Worse	Cost Growth>0	25 (52.1%)	2 (12.5%)	27			
Total		48	16	64			

Percent Design prior to Constr.		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~3.2	3.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	5 (31.3%)	31 (67.4%)	36	0.32	0.012 **	0.018 **
Worse	Cost Growth>0	11 (68.8%)	15 (32.6%)	26			
Total		16	46	62			

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	14 (46.7%)	17 (73.9%)	31	0.27	0.046 **	0.055 *
Worse	Cost Growth>0	16 (53.3%)	6 (26.1%)	22			
Total		30	23	53			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.1	8.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	5 (26.3%)	19 (67.9%)	24	0.41	0.005 ***	0.008 ***
Worse	Cost Growth>0	14 (73.7%)	9 (32.1%)	23			
Total		19	28	47			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		No	Yes	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	40 (54.1%)	27 (60.0%)	67	0.06	0.526	0.571
Worse	Cost Growth>0	34 (45.9%)	18 (40.0%)	52			
Total		74	45	119			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~2.1	2.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	41 (50.0%)	7 (77.8%)	48	0.17	0.113	0.164
Worse	Cost Growth>0	41 (50.0%)	2 (22.2%)	43			
Total		82	9	91			

Contingency Table Analysis Results for Budget Factor Performance of Contractor Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.8	6.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (33.3%)	18 (81.8%)	19	0.37	0.065 *	0.133
Worse	Cost Growth>0	2 (66.7%)	4 (18.2%)	6			
Total		3	22	25			

FEP		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (57.1%)	20 (83.3%)	24	0.26	0.145	0.302
Worse	Cost Growth>0	3 (42.9%)	4 (16.7%)	7			
Total		7	24	31			

Alignment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5	5~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (50.0%)	18 (81.8%)	21	0.30	0.111	0.144
Worse	Cost Growth>0	3 (50.0%)	4 (18.2%)	7			
Total		6	22	28			

Partnering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.4	6.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	33 (68.8%)	6 (85.7%)	39	0.12	0.356	0.660
Worse	Cost Growth>0	15 (31.3%)	1 (14.3%)	16			
Total		48	7	55			

Team Building		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0	0~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	42 (72.4%)	1 (25.0%)	43	0.25	0.047 **	0.082 *
Worse	Cost Growth>0	16 (27.6%)	3 (75.0%)	19			
Total		58	4	62			

Change Management		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.7	7.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	11 (55.0%)	33 (82.5%)	44	0.29	0.023 **	0.032 **
Worse	Cost Growth>0	9 (45.0%)	7 (17.5%)	16			
Total		20	40	60			

Contingency Table Analysis Results for Budget Factor Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Constructability		Implementation Level		
Performance		0~3.8	3.8~10	Total
Better	Cost Growth<=0	2 (22.2%)	35 (79.5%)	37
Worse	Cost Growth>0	7 (77.8%)	9 (20.5%)	16
Total		9	44	53

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.47	0.001 ***	0.002 ***

Project Risk Assessment		Implementation Level		
Performance		0~1.1	1.1~10	Total
Better	Cost Growth<=0	3 (37.5%)	37 (78.7%)	40
Worse	Cost Growth>0	5 (62.5%)	10 (21.3%)	15
Total		8	47	55

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.33	0.016 **	0.028 **

Planning for Startup		Implementation Level		
Performance		0~6.1	6.1~10	Total
Better	Cost Growth<=0	4 (40.0%)	18 (81.8%)	22
Worse	Cost Growth>0	6 (60.0%)	4 (18.2%)	10
Total		10	22	32

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.02	0.018 **	0.037 **

Zero Accident Technique		Implementation Level		
Performance		0~5.6	5.6~10	Total
Better	Cost Growth<=0	1 (33.3%)	11 (50.0%)	12
Worse	Cost Growth>0	2 (66.7%)	11 (50.0%)	13
Total		3	22	25

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.42	0.588	1.000

Timely Engineering		Implementation Level		
Performance		0~7.6	7.6~10	Total
Better	Cost Growth<=0	18 (62.1%)	24 (72.7%)	42
Worse	Cost Growth>0	11 (37.9%)	9 (27.3%)	20
Total		29	33	62

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.11	0.370	0.423

Accurate Engineering		Implementation Level		
Performance		0~5.8	5.8~10	Total
Better	Cost Growth<=0	4 (40.0%)	39 (72.2%)	43
Worse	Cost Growth>0	6 (60.0%)	15 (27.8%)	21
Total		10	54	64

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.25	0.046 **	0.068 *

Contingency Table Analysis Results for Budget Factor Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (50.0%)	9 (60.0%)	10	0.07	0.787	1.000
Worse	Cost Growth>0	1 (50.0%)	6 (40.0%)	7			
Total		2	15	17			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.1	6.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (33.3%)	31 (75.6%)	34	0.35	0.014 **	0.022 **
Worse	Cost Growth>0	6 (66.7%)	10 (24.4%)	16			
Total		9	41	50			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		No	Yes	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	18 (62.1%)	18 (72.0%)	36	0.11	0.440	0.565
Worse	Cost Growth>0	11 (37.9%)	7 (28.0%)	18			
Total		29	25	54			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~1.1	1.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	24 (70.6%)	9 (81.8%)	33	0.11	0.464	0.699
Worse	Cost Growth>0	10 (29.4%)	2 (18.2%)	12			
Total		34	11	45			

Contingency Table Analysis Results for Schedule Factor Performance of Contractor Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.9	7.9~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (25.0%)	11 (73.3%)	13	0.46	0.026 **	0.039 **
Worse	Cost Growth>0	6 (75.0%)	4 (26.7%)	10			
Total		8	15	23			

FEP		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.7	6.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (27.3%)	10 (62.5%)	13	0.35	0.072 *	0.120
Worse	Cost Growth>0	8 (72.7%)	6 (37.5%)	14			
Total		11	16	27			

Alignment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.3	5.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (16.7%)	11 (57.9%)	12	0.35	0.078 *	0.160
Worse	Cost Growth>0	5 (83.3%)	8 (42.1%)	13			
Total		6	19	25			

Partnering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.3	7.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	19 (41.3%)	2 (66.7%)	21	0.12	0.390	0.569
Worse	Cost Growth>0	27 (58.7%)	1 (33.3%)	28			
Total		46	3	49			

Team Building		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	12 (35.3%)	12 (54.5%)	24	0.19	0.155	0.178
Worse	Cost Growth>0	22 (64.7%)	10 (45.5%)	32			
Total		34	22	56			

Change Management		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.5	8.5~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	8 (28.6%)	14 (56.0%)	22	0.28	0.043 **	0.055 *
Worse	Cost Growth>0	20 (71.4%)	11 (44.0%)	31			
Total		28	25	53			

Contingency Table Analysis Results for Schedule Factor Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.4	7.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	13 (32.5%)	7 (87.5%)	20	0.42	0.004 ***	0.006 ***
Worse	Cost Growth>0	27 (67.5%)	1 (12.5%)	28			
Total		40	8	48			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.7	7.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	16 (37.2%)	5 (83.3%)	21	0.31	0.032 **	0.072 *
Worse	Cost Growth>0	27 (62.8%)	1 (16.7%)	28			
Total		43	6	49			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.1	6.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (25.0%)	11 (50.0%)	13	0.02	0.222	0.407
Worse	Cost Growth>0	6 (75.0%)	11 (50.0%)	17			
Total		8	22	30			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	12 (42.9%)	5 (55.6%)	17	0.22	0.506	0.703
Worse	Cost Growth>0	16 (57.1%)	4 (44.4%)	20			
Total		28	9	37			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.2	7.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	8 (38.1%)	14 (41.2%)	22	0.03	0.821	1.000
Worse	Cost Growth>0	13 (61.9%)	20 (58.8%)	33			
Total		21	34	55			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (22.2%)	21 (43.8%)	23	0.16	0.227	0.288
Worse	Cost Growth>0	7 (77.8%)	27 (56.3%)	34			
Total		9	48	57			

Contingency Table Analysis Results for Schedule Factor Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0	0~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	0 (0.0%)	6 (46.2%)	6	0.32	0.215	0.486
Worse	Cost Growth>0	2 (100.0%)	7 (53.8%)	9			
Total		2	13	15			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.1	8.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	5 (29.4%)	13 (46.4%)	18	0.17	0.259	0.351
Worse	Cost Growth>0	12 (70.6%)	15 (53.6%)	27			
Total		17	28	45			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		No	Yes	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	11 (44.0%)	8 (34.8%)	19	0.09	0.514	0.566
Worse	Cost Growth>0	14 (56.0%)	15 (65.2%)	29			
Total		25	23	48			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0	0~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	8 (47.1%)	11 (44.0%)	19	0.03	0.845	1.000
Worse	Cost Growth>0	9 (52.9%)	14 (56.0%)	23			
Total		17	25	42			

Contingency Table Analysis Results for Safety Performance of Contractor Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.2	8.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (40.0%)	5 (71.4%)	9	0.31	0.201	0.335
Worse	Cost Growth>0	6 (60.0%)	2 (28.6%)	8			
Total		10	7	17			

FEP		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7	7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (25.0%)	7 (77.8%)	9	0.53	0.030 **	0.057 *
Worse	Cost Growth>0	6 (75.0%)	2 (22.2%)	8			
Total		8	9	17			

Alignment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (14.3%)	7 (70.0%)	8	0.55	0.024 **	0.050 **
Worse	Cost Growth>0	6 (85.7%)	3 (30.0%)	9			
Total		7	10	17			

Partnering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.1	5.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	10 (34.5%)	6 (75.0%)	16	0.34	0.041 **	0.055 *
Worse	Cost Growth>0	19 (65.5%)	2 (25.0%)	21			
Total		29	8	37			

Team Building		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.4	7.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	13 (36.1%)	4 (80.0%)	17	0.29	0.062 *	0.141
Worse	Cost Growth>0	23 (63.9%)	1 (20.0%)	24			
Total		36	5	41			

Change Management		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.7	7.7~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (20.0%)	14 (56.0%)	17	0.35	0.026 **	0.046 **
Worse	Cost Growth>0	12 (80.0%)	11 (44.0%)	23			
Total		15	25	40			

Contingency Table Analysis Results for Safety Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.3	5.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	3 (23.1%)	11 (55.0%)	14	0.32	0.070 *	0.087 *
Worse	Cost Growth>0	10 (76.9%)	9 (45.0%)	19			
Total		13	20	33			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~1.3	1.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (14.3%)	15 (46.9%)	16	0.25	0.112	0.206
Worse	Cost Growth>0	6 (85.7%)	17 (53.1%)	23			
Total		7	32	39			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.9	4.9~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (25.0%)	7 (46.7%)	8	0.02	0.435	0.603
Worse	Cost Growth>0	3 (75.0%)	8 (53.3%)	11			
Total		4	15	19			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.2	7.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (20.0%)	10 (50.0%)	12	0.18	0.114	0.235
Worse	Cost Growth>0	8 (80.0%)	10 (50.0%)	18			
Total		10	20	30			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.3	4.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (40.0%)	16 (44.4%)	18	0.03	0.851	1.000
Worse	Cost Growth>0	3 (60.0%)	20 (55.6%)	23			
Total		5	36	41			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.3	4.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (40.0%)	16 (42.1%)	18	0.01	0.929	1.000
Worse	Cost Growth>0	3 (60.0%)	22 (57.9%)	25			
Total		5	38	43			

Contingency Table Analysis Results for Safety Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0	0~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	0 (0.0%)	5 (62.5%)	5	0.40	0.087 *	0.182
Worse	Cost Growth>0	1 (100.0%)	3 (37.5%)	4			
Total		1	8	9			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0	0~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	6 (46.2%)	11 (44.0%)	17	0.02	0.899	1.000
Worse	Cost Growth>0	7 (53.8%)	14 (56.0%)	21			
Total		13	25	38			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0	0~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	9 (40.9%)	7 (38.9%)	16	0.02	0.897	1.000
Worse	Cost Growth>0	13 (59.1%)	11 (61.1%)	24			
Total		22	18	40			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~1.1	1.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	10 (47.6%)	2 (50.0%)	12	0.02	0.930	1.000
Worse	Cost Growth>0	11 (52.4%)	2 (50.0%)	13			
Total		21	4	25			

Contingency Table Analysis Results for Quality Performance of Contractor Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.2	8.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (40.0%)	6 (85.7%)	10	0.46	0.059 *	0.134
Worse	Cost Growth>0	6 (60.0%)	1 (14.3%)	7			
Total		10	7	17			

FEP		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (25.0%)	11 (84.6%)	12	0.55	0.022 **	0.053 *
Worse	Cost Growth>0	3 (75.0%)	2 (15.4%)	5			
Total		4	13	17			

Alignment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.2	4.2~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (33.3%)	13 (92.9%)	14	0.60	0.014 **	0.063 *
Worse	Cost Growth>0	2 (66.7%)	1 (7.1%)	3			
Total		3	14	17			

Partnering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0.1	0.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	18 (66.7%)	8 (80.0%)	26	0.13	0.431	0.688
Worse	Cost Growth>0	9 (33.3%)	2 (20.0%)	11			
Total		27	10	37			

Team Building		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.4	7.4~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	26 (72.2%)	4 (80.0%)	30	0.06	0.713	1.000
Worse	Cost Growth>0	10 (27.8%)	1 (20.0%)	11			
Total		36	5	41			

Change Management		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.6	8.6~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	16 (64.0%)	12 (80.0%)	28	0.17	0.285	0.477
Worse	Cost Growth>0	9 (36.0%)	3 (20.0%)	12			
Total		25	15	40			

Contingency Table Analysis Results for Quality Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.3	6.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	19 (73.1%)	6 (85.7%)	25	0.12	0.489	0.652
Worse	Cost Growth>0	7 (26.9%)	1 (14.3%)	8			
Total		26	7	33			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.3	8.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	28 (73.7%)	1 (100.0%)	29	0.10	0.552	1.000
Worse	Cost Growth>0	10 (26.3%)	0 (0.0%)	10			
Total		38	1	39			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~6.5	6.5~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	5 (50.0%)	8 (88.9%)	13	0.02	0.069 *	0.141
Worse	Cost Growth>0	5 (50.0%)	1 (11.1%)	6			
Total		10	9	19			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.1	7.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	5 (55.6%)	17 (81.0%)	22	0.42	0.149	0.195
Worse	Cost Growth>0	4 (44.4%)	4 (19.0%)	8			
Total		9	21	30			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	4 (44.4%)	25 (78.1%)	29	0.31	0.050 **	0.093 *
Worse	Cost Growth>0	5 (55.6%)	7 (21.9%)	12			
Total		9	32	41			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	5 (62.5%)	26 (74.3%)	31	0.10	0.503	0.665
Worse	Cost Growth>0	3 (37.5%)	9 (25.7%)	12			
Total		8	35	43			

Contingency Table Analysis Results for Quality Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	0 (0.0%)	7 (87.5%)	7	0.66	0.047 **	0.222
Worse	Cost Growth>0	1 (100.0%)	1 (12.5%)	2			
Total		1	8	9			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.1	8.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	9 (69.2%)	18 (72.0%)	27	0.03	0.858	1.000
Worse	Cost Growth>0	4 (30.8%)	7 (28.0%)	11			
Total		13	25	38			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		No	Yes	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	15 (68.2%)	14 (77.8%)	29	0.11	0.499	0.723
Worse	Cost Growth>0	7 (31.8%)	4 (22.2%)	11			
Total		22	18	40			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~1.1	1.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	12 (57.1%)	3 (75.0%)	15	0.13	0.504	0.626
Worse	Cost Growth>0	9 (42.9%)	1 (25.0%)	10			
Total		21	4	25			

Contingency Table Analysis Results for Business Performance of Contractor Projects

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

PDRI		Implementation Level		
Performance		0~7.5	7.5~10	Total
Better	Cost Growth<=0	4 (57.1%)	7 (77.8%)	11
Worse	Cost Growth>0	3 (42.9%)	2 (22.2%)	5
Total		7	9	16

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.22	0.377	0.596

FEP		Implementation Level		
Performance		0~8.1	8.1~10	Total
Better	Cost Growth<=0	6 (54.5%)	5 (83.3%)	11
Worse	Cost Growth>0	5 (45.5%)	1 (16.7%)	6
Total		11	6	17

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.29	0.235	0.333

Alignment		Implementation Level		
Performance		0~4.7	4.7~10	Total
Better	Cost Growth<=0	1 (25.0%)	10 (76.9%)	11
Worse	Cost Growth>0	3 (75.0%)	3 (23.1%)	6
Total		4	13	17

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.46	0.057 *	0.099 *

Partnering		Implementation Level		
Performance		0~5.1	5.1~10	Total
Better	Cost Growth<=0	16 (57.1%)	5 (62.5%)	21
Worse	Cost Growth>0	12 (42.9%)	3 (37.5%)	15
Total		28	8	36

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.05	0.786	1.000

Team Building		Implementation Level		
Performance		0~7.4	7.4~10	Total
Better	Cost Growth<=0	20 (57.1%)	4 (80.0%)	24
Worse	Cost Growth>0	15 (42.9%)	1 (20.0%)	16
Total		35	5	40

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.15	0.329	0.631

Change Management		Implementation Level		
Performance		0~7.7	7.7~10	Total
Better	Cost Growth<=0	6 (40.0%)	17 (70.8%)	23
Worse	Cost Growth>0	9 (60.0%)	7 (29.2%)	16
Total		15	24	39

Phi Coeff.	P-Value of Significance Test	
	Chi-Square	Fisher's Exact
0.30	0.057 *	0.094 *

Contingency Table Analysis Results for Business Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Constructability		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~3	3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	2 (40.0%)	18 (66.7%)	20	0.20	0.258	0.338
Worse	Cost Growth>0	3 (60.0%)	9 (33.3%)	12			
Total		5	27	32			

Project Risk Assessment		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~7.3	7.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	20 (58.8%)	3 (75.0%)	23	0.10	0.531	1.000
Worse	Cost Growth>0	14 (41.2%)	1 (25.0%)	15			
Total		34	4	38			

Planning for Startup		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.8	8.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	10 (55.6%)	1 (100.0%)	11	0.02	0.381	1.000
Worse	Cost Growth>0	8 (44.4%)	0 (0.0%)	8			
Total		18	1	19			

Zero Accident Technique		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~8.5	8.5~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	15 (55.6%)	2 (66.7%)	17	0.20	0.713	1.000
Worse	Cost Growth>0	12 (44.4%)	1 (33.3%)	13			
Total		27	3	30			

Timely Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.3	4.3~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (20.0%)	23 (65.7%)	24	0.31	0.051 *	0.138
Worse	Cost Growth>0	4 (80.0%)	12 (34.3%)	16			
Total		5	35	40			

Accurate Engineering		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~2.9	2.9~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (50.0%)	24 (60.0%)	25	0.04	0.779	1.000
Worse	Cost Growth>0	1 (50.0%)	16 (40.0%)	17			
Total		2	40	42			

Contingency Table Analysis Results for Business Performance of Contractor Projects (Continued)

*** Significance at α=0.01; ** Significance at α=0.05; * Significance at α=0.10

Alliance		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~5.8	5.8~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	0 (0.0%)	5 (62.5%)	5	0.40	0.236	0.444
Worse	Cost Growth>0	1 (100.0%)	3 (37.5%)	4			
Total		1	8	9			

Budget Accuracy		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~4.1	4.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	1 (50.0%)	21 (60.0%)	22	0.05	0.779	1.000
Worse	Cost Growth>0	1 (50.0%)	14 (40.0%)	15			
Total		2	35	37			

Fast Track		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~0	0~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	14 (66.7%)	9 (50.0%)	23	0.17	0.291	0.342
Worse	Cost Growth>0	7 (33.3%)	9 (50.0%)	16			
Total		21	18	39			

Modularization		Implementation Level			Phi Coeff.	P-Value of Significance Test	
Performance		0~1.1	1.1~10	Total		Chi-Square	Fisher's Exact
Better	Cost Growth<=0	12 (57.1%)	2 (66.7%)	14	0.06	0.754	1.000
Worse	Cost Growth>0	9 (42.9%)	1 (33.3%)	10			
Total		21	3	24			

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