A CORRELATIONAL STUDY ASSESSING THE RELATIONSHIPS AMONG INFORMATION TECHNOLOGY PROJECT COMPLEXITY, PROJECT COMPLICATION, AND PROJECT SUCCESS

by

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Abstract

The specific problem addressed in this study was the low success rate of information technology (IT) projects in the U.S. Due to the abstract nature and inherent complexity of software development, IT projects are among the most complex projects encountered. Most existing schools of project management theory are based on the rational systems view; however, for projects with a high degree of complexity, a complex adaptive systems view more effectively describes the full range of project behavior. To investigate the problem, a distinction was made between project complexity and project complication. To help reduce the frequency of IT project failure, project attributes that contribute to complexity and complication were identified from literature, and a survey instrument was developed to measure and investigate relationships between IT project complication, IT project complexity, and IT project success. The survey was tested and administered to the U.S.-based membership of the Project Management Institute's Information Systems Community of Practice (PMI IS CoP). A total of 235 qualified responses were received, exceeding the minimum sample size of n = 115 determined by power analysis. The survey data was analyzed and transformed, and parametric Pearson's correlation coefficients and nonparametric Kendall's tau_b and Spearman's rho correlations were determined. Results indicated IT project complexity and IT project complication were positively correlated, but IT project complexity had a greater negative correlation with IT project success. The study expanded the application of complex adaptive systems theory to project management theory by providing empirical evidence of a distinction between project complexity and project complication, and between their respective relationships with project success. Implications for practice and future research include identifying and managing project attributes related to

complexity to increase the likelihood of project success, and further investigation of project attributes related to project complexity, complication, and success.

Dedication

To Lynn and Ashley, who supported me in working on this way longer than planned. I love you both always.

Acknowledgments

With sincere appreciation for my academic advisor, Laura Hutt; my committee members, Werner D. (Don) Gottwald and Freda J. Turner; and especially my faculty mentor and committee chair, Lawrence R. (Lonny) Ness.

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CHAPTER 1. INTRODUCTION

There is a difference between complexity and complication (Cilliers, 1998). An entity or system which can be defined completely in terms of its components or elements, no matter how numerous, can be described as *complicated*. When the interactions within and among the elements of a system and between the system and its environment cannot be separated, analyzed, and described completely as separate components, the system is said to be *complex* (Cilliers). Furthermore, the interactions between the components of a complex system have a tendency to change over time as the system adapts to its environment (Buckley, 1968; Maturana & Varela, 1980). In such a *complex adaptive system*, outcomes can be unpredictable and uncontrollable (Gabriel, 1998; Lorenz, 1972). *Project complexity* is defined in this study as the tendency of a project to exhibit the characteristics of complexity and the behaviors of a complex adaptive system.

Introduction to the Problem

The practice of management has theoretical origins in military strategy (Mintzberg, 1994, 2004), and is typically defined as the application of "resources of production" (Drucker, 1954, p. 3) to make "desired results come to pass" (p. 11). Similarly, project management has been defined as "the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements" (Project Management Institute, 2008a, p. 6). Although these and other similar definitions are widely accepted, they are based on underlying assumptions that the world is structured, logical, and linear (Gleick, 1988; Wheatley, 1992, 1999).

In the emerging field of chaos and complexity theory (Lorenz, 1963, 1993; Waldrop, 1992), no such assumptions are made. Instead, a world view is constructed in which complex systems are highly sensitive to changes in initial conditions (Garmon, 2004), outcomes are often unpredictable (Lorenz, 1972), problems change in response to attempted solutions (Churchman, 1967; Rittel & Webber, 1973), and control is recognized as more illusion than reality (Gabriel, 1998). In spite of human preferences, chaos and complexity do not conform to traditional management theories (Gabriel, 1998).

For organizational leaders and project teams engaged in information technology (IT) projects, project complexity and complication present a growing threat to project predictability, control, and success (Brockhoff, 2006; Cavaleri & Reed, 2008). Despite decades of effort toward software process improvement (Paulk, 1999; Software Engineering Institute, 2006) and project management maturity (J. K. Crawford, 2006; Dinson, 2003; Jugdev & Thomas, 2002; Pennypacker & Grant, 2003; Project Management Institute, 2008b), IT project failure rates appear to be increasing (Standish Group, 2008, 2009).

Information technology project failure is costly and common. The estimated annual cost of IT project failures and overruns in U.S. organizations has grown from $200 billion (Standish Group, 2001b) to $1.2 trillion (Sessions, 2009). Project success rates that appeared to be improving in the mid-2000s (see Figure 1) have begun to decline again (Standish Group, 2007, 2009). While the perception of IT project success and failure may be influenced by the choice of project success criteria (A. Griffin & Page, 1993; Jugdev & Muller, 2005), only 32% of U.S. IT projects in 2008 were completed on time and under budget with all their original requirements; 44% were completed late and over budget with reduced scope, and 24% were canceled or never implemented (Standish Group, 2009).

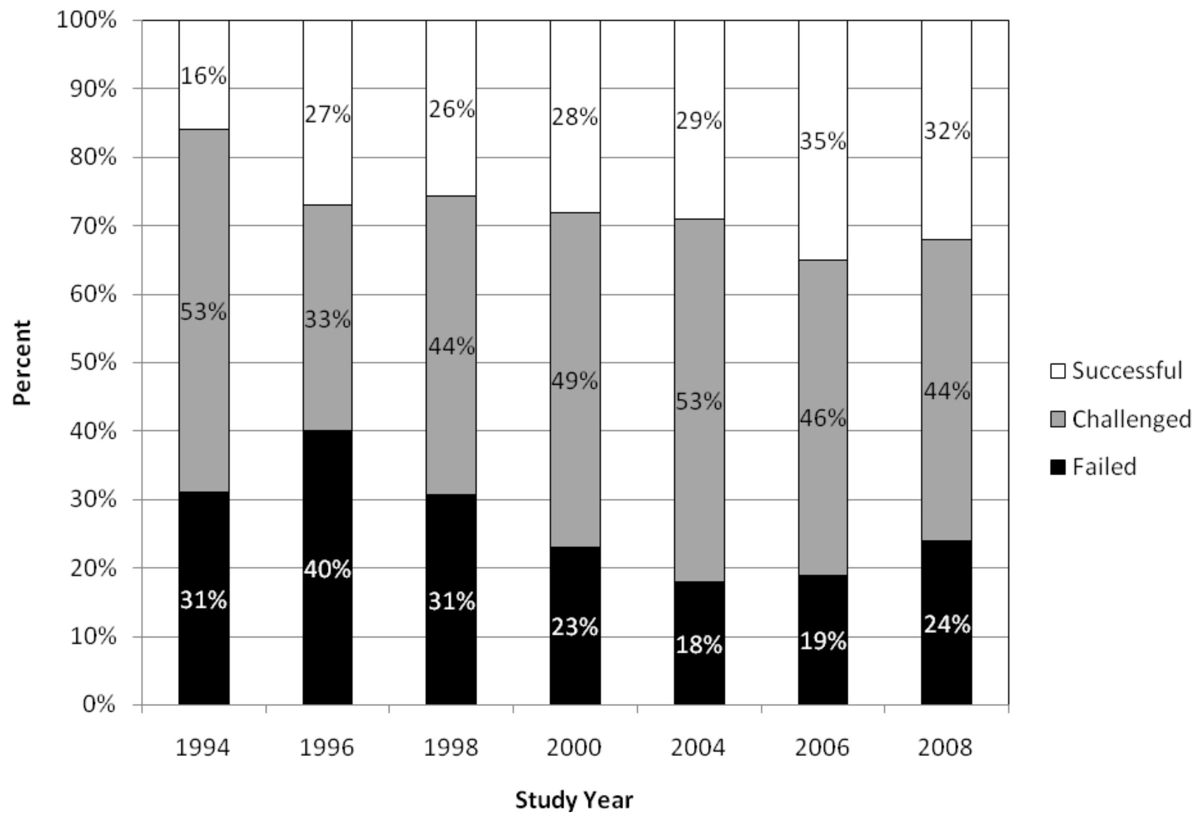


Figure 1. Information technology project percentages considered successful, challenged, and failed from 1994 to 2008.
The data in this figure are from *Chaos Summary*, 2009, by the Standish Group. Boston, MA: Author.

Despite Carr's (2003) assertion that IT "doesn't matter" (p. 41), the strategic importance of IT continues to grow for organizations in the United States and worldwide (Melville, Kraemer, & Gurbaxani, 2004; Neirotti & Paolucci, 2007). While Carr accurately portrayed the increasing commoditization of IT infrastructure, he neglected the role of IT in supporting new business initiatives and creating new forms of communication, collaboration, and recreation (Pisello, 2005). More recently, Carr (2008) acknowledged that the rapid growth of networked computing had a historical parallel in electrification, yet its future effects on society were likely to be even more significant.

The growing disparity between the strategic importance of IT and the frequent failure of IT projects has been attributed, at least partially, to increasing complication and complexity of IT and IT projects (Daniel, 2007; Hassan & Holt, 2003; Ko, Xia, & Lee, 2006; Little, 2005; Xia & Lee, 2004). Each appears to contribute to the problem in a different way. Project complication, typically caused by project characteristics such as large numbers of individual components, extensive and detailed project requirements, long project durations, and large or virtual project teams, makes project execution more difficult and time-consuming, and increases project cost and risk (Cilliers, 1998; Hass, 2009). Project complexity, on the other hand, can result from other factors including nonlinear interactions between project components, extensive organizational and technological change, ambiguous or unknown project objectives and requirements, external dependencies and constraints, and political or strategic environmental influences. Complexity tends to cause project behavior to adapt and change, new forms of project interaction to emerge, project risk to increase significantly, and project schedules, budgets, and outcomes to become unpredictable (Hass, 2009; Shenhar & Dvir, 2007b; Xia & Lee, 2004, 2005). Information technology projects, due to their inherent characteristics, tend to be both complicated and complex (Benbya & McKelvey, 2006; Boisot, 2006). Traditional project management methods based on the rational systems view (Fayol, 1949/1919; March & Simon, 1958; Taylor, 1919) appear to be less effective when applied to projects exhibiting high degrees of complexity and characteristics of complex adaptive systems (Buckley, 1968; Thietart & Forgues, 1995). In addition, project success criteria based on the assumptions of predictability and control characteristic of the rational systems view may unintentionally reduce the likelihood of success on complex IT projects (Baccarini, 1999; J. Johnson, 2006; Nogeste & Walker, 2008; Schulte, 2004).

In summary, there are problems in practice and deficiencies in the literature. Organizational leaders and project teams continue to apply traditional project management methods and project success criteria to complex IT projects with less than completely successful results. Researchers have not yet fully addressed the applicability of various schools of project management theory to projects of differing types and differing degrees of complexity. Models of project complexity are now emerging but remain largely untested (B. R. R. Butler, et al., 2004; Hass, 2009; Singh & Singh, 2002; Whitty & Maylor, 2007; Xia & Lee, 2005). Literature on the identification and selection of project success criteria and their relationship to project success, particularly for complex IT projects, is also limited (Agarwal & Rathod, 2006; Atkinson, 1999; Ojiako, Johansen, & Greenwood, 2008; Shenhar & Wideman, 1996a).

For this study, the applicability of various schools of project management theory to complex IT projects was reviewed and analyzed, and a systematic approach to assessing the complexity of IT projects was synthesized. In addition, an analysis of the identification and selection of project success criteria for complex IT projects was performed, and an investigation of the relationships between project complexity, project complication, and project success was undertaken. The objective of this study was to contribute to the knowledge and practice of complex IT project management.

Background of the Study

Project management is a cross-disciplinary field with theoretical foundations in operations research, systems theory, organizational behavior, business management, and law (Kerzner, 2006; Lewis, 2005; Project Management Institute, 2008a). Its broad range of academic and practical origins has led some researchers to conclude it lacks a consistent underlying body of theory (Betts & Lansley, 1995; Jugdev, 2004; Koskela & Howell, 2002). Other researchers have identified at least nine major schools of project management theory (Anbari, Bredillet, & Turner, 2008; Bredillet, 2007a, 2007b, 2007c, 2008a, 2008b, 2008c) and several additional less comprehensive theoretical perspectives (Cicmil & Hodgson, 2006; Crawford, Pollack, & England, 2006; Williams, 1999).

The broad range of project management theory has been analyzed using several approaches including historical timelines (Anbari, et al., 2008), project categories (Archibald & Voropaev, 2004; Shenhar & Dvir, 1996), contingency theory (Shenhar, 2001), and the resource-based view (Jugdev, 2004). Since projects are essentially temporary organizations (J. R. Turner & Muller, 2003), the organizational paradigms from general systems theory have provided another useful analytical framework. The rational, natural, and open systems views have been widely applied to the study of organizations (Katz & Kahn, 1966; Parsons, 1960; Scott, 2003; J. D. Thompson, 2003). The complex adaptive systems view (Buckley, 1968) has extended the systems model to accommodate complexity and emergent forms of organization (Gleick, 1988; Wheatley, 1999). Despite a few examples in the literature (Bardyn & Fitzgerald, 1996; Fitzgerald & Bardyn, 2006; Hass, 2009), complexity theory (R. Lewin, 1992; Waldrop, 1992) has not been widely applied in project management practice (Jaafari, 2003). Depending on conditions such as their degree of interconnectedness and the extent to which they address unknowns, projects and organizations can assume the characteristics of complex adaptive systems (Churchman, 1967; Rittel & Webber, 1973); however, the existing body of project management theory is still predominantly based on the rational systems view (Fayol, 1949/1919; March & Simon, 1958; Taylor, 1919).

Projects can be both complicated and complex (Brooks, 1995; Xia & Lee, 2004). Some researchers have combined the two concepts (Hass, 2009; Shenhar & Dvir, 2007b), while others have differentiated between them (Cilliers, 1998). Projects tend to be more complicated when requirements are extensive and detailed, project cost is high, project duration is long, and the project team is large, geographically dispersed, or inexperienced (Cilliers, 1998; Hass, 2009). Project complexity, on the other hand, tends to occur when requirements are unclear and volatile, the problem or opportunity is not clearly defined, the project incorporates a high degree of technological or organizational change, or there are significant political and social influences or external dependencies and constraints (Baccarini, 1996; Jaafari, 2003; Whitty & Maylor, 2007). While project complication can make projects more difficult to manage, project complexity can cause project behavior and outcomes to become unmanageable and unpredictable (Benbya & McKelvey, 2006; Xia & Lee, 2004). Compounding the problem, even experienced practitioners tend to overlook and underestimate project complexity (Daniel, 2007).

Information technology projects, in particular, are often made more complicated and complex by the inherent characteristics of software and information technology (Hassan & Holt, 2003; McDonald, 2001), and by the organizational change which often accompanies them (Sauer & Cuthbertson, 2003). Researchers have also identified strong relationships between IT project complexity and IT project risk (Jiang, Klein, & Ellis, 2002). Many suggested frameworks for assessing IT project risk have actually measured aspects of project complication and project complexity (Statz, Oxley, & O'Toole, 1997; Tesch, Kloppenborg, & Frolick, 2007).

As a result, IT project failure is more frequent than IT project success (Standish Group, 2009). Researchers have identified many potential causes of IT project failure including lack of alignment between business and project objectives (Hartman & Ashrafi, 2002), failure to learn from past mistakes (Ewusi-Mensah, 1997; Ewusi-Mensah & Przasnyski, 1995; Glass, 1998), lack of senior management support (Standish Group, 1999), and inadequate project management methodologies (J. Johnson, 2006). The most significant underlying cause of IT project failure, however, may be unrecognized and underestimated project complexity (Jiang, et al., 2002; Sauer & Cuthbertson, 2003).

Consensus appears to be growing that new approaches to project management theory and practice are needed (Sauer & Reich, 2009; Winter, Smith, Morris, & Cicmil, 2006). Agile project management (Neudorf, 2008) and extreme project management (D. DeCarlo, 2004, 2005, 2007) are examples of an emerging school of project management theory based on the complex adaptive systems view (Austin, Newton, Steele, & Waskett, 2002; Baccarini, 1996; G. S. Griffin, 1996). Literature indicates several models of project complexity are also emerging, including those targeted at information systems development projects (Xia & Lee, 2004, 2005), and new product development projects (Ahn & Kim, 2002; Kim & Wilemon, 2003, 2009). The project complexity model developed by Hass (2009) is among the most comprehensive to date.

Statement of the Problem

The management problem considered in this study is the tendency for 68% of U.S. IT projects to be considered unsuccessful (Standish Group, 2009); consequently, the management imperative addressed in this study is the imperative to improve the IT project success rate. Many alternative approaches to improving IT project success have been investigated by researchers and implemented by practitioners (Baccarini, 1999; J. K. Crawford, 2006; White & Fortune, 2002), but the continuing low project success rate indicates the severity and inscrutability of the problem (Kappelman, McKeeman, & Zhang, 2006). Management still faces difficult questions about identifying symptoms and causes of IT project failure, distinguishing between symptoms and causes, and addressing the causes (Jiang, et al., 2002; Sauer & Cuthbertson, 2003).

The specific problem addressed in this study is the low success rate of IT projects in the U.S. Researchers at the Standish Group (2009) found that only 32% of IT projects undertaken in 2008 in the U.S. were considered successful, while 68% were late and over budget or canceled. Some researchers have questioned the validity of the Standish figures (El Emam & Koru, 2008; Eveleens & Verhoef, 2009; Glass, 2006b), but there is widespread consensus regarding the extent and severity of the problem (Kappelman, et al., 2006; Linberg, 1999; Rost, 2004; Yeo, 2002). The low apparent success rate on IT projects has been attributed at least partially to inadequate application of existing project management practices and guidelines (Jugdev & Thomas, 2002; Sidenko, 2006); however, another problem has been undiagnosed and unmitigated project complexity (Benbya & McKelvey, 2006).

Information technology projects, due to their inherent technical complexity, their application to complex business problems, and the degree to which they address unknowns, tend to be among the most complex of all projects (Xia & Lee, 2004). Project success rates may be further reduced when project success criteria appropriate for less complex projects are applied to projects with high degrees of complexity (Atkinson, 1999; Lim & Mohamed, 1999; Westerveld, 2003). Without a reliable way to diagnose IT project complexity, choose appropriate project management methods and practices, and identify and select appropriate project success criteria, IT project teams appear likely to fail nearly 70% of the time.

Gaps exist in the literature on the relationship between IT project complexity and complication, and their individual relationships to IT project success. Further investigation into these relationships extends the body of project management theory by improving the understanding of project characteristics related to project success. To date, no models of project complexity have differentiated between project characteristics likely to increase project complexity and those likely to increase project complication. Both reduce the likelihood of project success, but in significantly different ways (Cilliers, 1998). In addition, empirical studies of the relationship between project complexity and project success are only beginning to emerge (Hass, 2009; Xia & Lee, 2004).

Purpose of the Study

The purpose of this quantitative, correlational study was to investigate the relationships between IT project complication, IT project complexity, and IT project success to help reduce the incidence of IT project failure. The role of IT in advancing strategic and tactical objectives makes it critically important to organizational leaders (Tallon, Kraemer, & Gurbaxani, 2000), yet 68% of IT projects are considered unsuccessful (Standish Group, 2009). This study was designed to improve the understanding of the project characteristics that contribute to both IT project complexity and IT project complication, and how they are related to IT project success and failure.

For this purpose, a model of IT project complexity and complication was synthesized from existing literature, validated, and then used to assess measured complexity and complication for a sample of IT projects. The relationships between project complexity, complication, and success were then examined in order to assess their direction and extent, thereby helping improve the understanding of how IT project complexity and IT project complication are related to project success. Ultimately, the study results may lead to more effective project management and more appropriate measurements of project success for complex IT projects.

Rationale

Investigating the relationships between IT project complexity, IT project complication, and IT project success is relevant and important because of its potential impact on both the practice and the study of IT project management. This study was performed primarily to examine the relationship between IT project complexity and IT project success. In addition, the relationships between IT project complication and IT project success, and between IT project complexity and IT project complication were also evaluated. The results of this study improve the understanding of the perception and prevalence of IT project complexity in current practice, and contribute to the IT project management body of knowledge with empirical data on IT project complexity. In addition, the study supports efforts to manage IT project complexity more effectively and differently from IT project complication, hence improving the likelihood of success on complex IT projects.

Research Questions

In this study, the purpose of advancing the understanding of IT project success and failure was addressed by distinguishing between project complication and project complexity (Cilliers, 1998; K. A. Richardson, Cilliers, & Lissack, 2000). Both were hypothesized as having a negative influence on project success, especially when they are unrecognized, underestimated, and unmanaged (Benbya & McKelvey, 2006; Brockhoff, 2006; Cavaleri & Reed, 2008). The study was designed to investigate the degree to which IT project complication and IT project complexity are related, and the degree to which IT project complication and complexity are related to IT project success. Evidence of correlation between project complication, project complexity, and project success found in this study might help management choose more effective project management approaches and increase the likelihood of project success (Ceschi, Sillitti, Succi, & De Panfilis, 2005). The following research questions were considered:

RQ1: To what extent, if any, is IT project complexity related to IT project complication?

RQ2: To what extent, if any, is IT project complexity related to IT project success?

RQ3: To what extent, if any, is IT project complication related to IT project success?

RQ4: To what extent, if any, is IT project complexity more strongly related to IT project success than is IT project complication?

The conceptual model (see Figure 2) graphically depicts the relationships investigated. The arrow between ITPCx and ITPCn is bi-directional since they were treated as related, but independent constructs. The bold arrow between ITPCx and ITPS indicates this relationship was the primary focus of this study, while the dashed arrow between ITPCn and ITPS indicates this relationship was considered secondary.

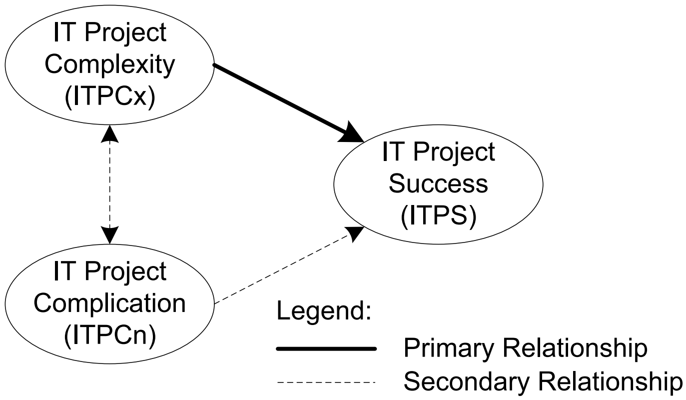


Figure 2. Conceptual model of the relationships between IT project complication, complexity, and success.

Stated as hypotheses, the relationships investigated in this study were as follows:

$H1_0$: IT project complexity is not correlated with IT project complication

$H1_A$: IT project complexity is correlated with IT project complication

$H2_0$: IT project complexity is not correlated with IT project success

$H2_A$: IT project complexity is correlated with IT project success

$H3_0$: IT project complication is not correlated with IT project success

$H3_A$: IT project complication is correlated with IT project success

$H4_0$: IT project complication has an equal or greater correlation with IT project success than does IT project complexity

$H4_A$: IT project complexity has a greater correlation with IT project success than does IT project complication

Together, these research questions and hypotheses were intended to investigate the relationship between IT project complexity and complication, and the relationships of each with IT project success, with the objective of advancing the knowledge and practice of complex IT project management and increasing the likelihood of IT project success.

Significance of the Study

This study was conducted to improve the understanding of project complexity within the context of information technology projects. In addition, it was intended to provide insight into the extent to which project complexity is recognized and addressed by IT project management practitioners, the relationship between IT project complexity and IT project success, and the relationship between IT project complication and IT project success. Potential benefits of the study included empirical evidence that IT project complexity had a stronger relationship with IT project success than did IT project complication, leading to further studies in managing IT project complexity and IT project complication differently and more effectively, and thus reducing the likelihood of IT project failure.

For practitioners, the study was intended to contribute to more effective diagnosis of IT project complexity and more appropriate selection of project management practices for complex IT projects. In addition, it may have helped improve the likelihood of project success by providing incentive for adopting broader definitions of complex IT project success. For researchers, the study was designed to test the relationship between IT project complexity and IT project success, and to assess whether complexity was more strongly related to project success than was complication. It is hoped that the study finding can be applied to further studies of IT project complexity, project complexity, and other practical applications. In the words of Kurt Lewin (1945), "nothing is as practical as a good theory" (p. 129).

Definition of Terms

In order to address the relationship between IT project complexity and IT project success, it is beneficial to define some key terms from project management theory and complexity theory, and to distinguish between project critical success factors and project success criteria. Brief definitions of each of these terms follow.

Adaptivity. The tendency or ability of systems or entities to respond to changes in their environments by adopting new structures or forms. Buckley (1968) extends the definition to include the ability to selectively retain and build upon previous adaptations to accommodate increasing *complexity*.

Autopoiesis. A characteristic of adaptive entities enabling them to self-organize without external control. The word was adapted from the Greek *poiesis* in 1972 by biologist Humberto Maturana to describe the distinctive characteristic of living systems, self-production (Maturana & Varela, 1980).

Complex adaptive systems. Specifically, systems exhibiting the characteristics of both *complexity* and *adaptivity*. More generally, systems which (a) respond to, and influence their environments; (b) adapt to improve their performance; (c) are intrinsically non-linear; (d) exhibit self-organizing, emergent behavior; (e) are highly sensitive to small variations in initial conditions, (f) are usually in a sub-optimal state, and (g) often react to external stimuli or interventions with unexpected responses (Pines, 1998). In the context of sociological entities, systems whose properties include (a) emergence and self-organization, in which interactions between participants are unplanned and uncontrolled, allowing new structures and forms of behavior to develop; (b) connectivity and interdependence with other systems and their environments; (c) sub-optimization and imperfection resulting from the need to conserve energy to adapt to continuous change; (d) simple structures and rules allowing (e) variety and ambiguity; (f) iterative behavior that amplifies small variations in inputs; and (g) gravitation toward the *edge of chaos* where equilibrium and chaos exist in constant tension (Fryer, 2008 as cited in Hass, 2009).

Complexity. The degree to which the interactions within and among the elements of a system and between the system and its environment cannot be analyzed and described as separate components, coupled with the tendency for these interactions to change over time as a result of *adaptation* and *emergence* (Cilliers, 1998). Not to be confused with *complication*.

Complication. As opposed to *complexity*, complication tends to result from large numbers of individual project components and detailed project requirements, and is exacerbated when project schedules are longer, and project teams and budgets are larger (Hass, 2009; Shenhar & Dvir, 2007b). In spite of the resulting increases in scope, duration, and difficulty, complicated projects retain the ability to be fully defined by analyzing and describing their individual components, even if they are numerous and detailed (Cilliers, 1998).

Critical success factors. Conditions, attributes, or behaviors determined to have a significant, or critical, impact on the outcome of an activity or process. In practice, "those few things that must go well to ensure success for a manager or an organization" (Boynton & Zmud, 1984, p. 17). Not to be confused with *project success criteria*.

Project complexity. The tendency of a project to exhibit the characteristics of *complexity* and the behaviors of a *complex adaptive system*. Influenced by, but distinct from, the degree of *complication* exhibited by the project's components or subsystems. In practice, it is assessed by a number of criteria determined theoretically or empirically to increase the likelihood that a project's behavior will become *complex* (Baccarini, 1996; Hass, 2009; Xia & Lee, 2005).

Project success criteria. The criteria or standards by which project success is evaluated or measured. Applied to either the *process* or the *product* of the project (Baccarini, 1999).

Assumptions and Limitations

Pragmatic researchers acknowledge the premise that research is ideologically biased and therefore not value-free (Janesick, 2000). The author, an IT project management practitioner and educator, a Project Management Institute (PMI) member, a certified Project Management Professional (PMP), and a member of the PMI Information Systems Community of Practice (IS CoP)—formerly known as the Information Systems Special Interest Group (IS-SIG)—undoubtedly brings personal bias to the study. Potential limitations of the study also include the use of a specialized and self-selected group for the survey research. It is recognized that certified PMPs belonging to the PMI IS CoP may be relatively advanced practitioners of IT project management, however, due to its primary focus and mission on advancing the practice of IT project management (PMI-ISSIG, 2008; PMI IS CoP, 2011), the group is well-suited for research on the prevalence, extent, and effects of IT project complexity.

Limitations to internal validity inherent in quantitative correlational research design must also be acknowledged (Cronbach, 1957; Fraenkel & Wallen, 1993; Mitchell, 1985). Unlike in experimental research, the inability to control for environmental factors reduces validity due to the possibility of confounding variables (Mitchell, 1985). This can be addressed through validity testing of the constructs used to measure the study variables (Drasgow & Miller, 1982); in this study, Cronbach's Alpha is utilized for this purpose.

Inherent in sociological research is the opportunity for selection bias and its effects on external validity. Whenever a non-random sample of a survey population is chosen, selection bias should be assumed (Berk, 1983; Winship & Mare, 1992). Of the two primary forms of selection bias identified by Heckman (1979), self selection and researcher selection, the tendency for research subjects to respond non-randomly in a self-selecting manner poses the greater threat to the external validity of this study. Since data gathering methods that force participants to respond are usually unethical or illegal, most samples in sociological research are biased (Stolzenberg & Relles, 1990, 1997). Although several techniques for identifying and estimating selection bias have been suggested, no available techniques consistently eliminate such bias (Winship & Mare, 1992). The sampling frame used in this study, the PMI IS CoP, is a self-selecting group. The population has been used extensively for similar studies (Mishra, Sinha, & Thirumalai, 2009; Wallace, Keil, & Rai, 2004; Xia & Lee, 2005), however, generalization of conclusions from this study must be considered in the context of a potentially biased sample.

In this study, the sources and nature of IT project complexity and complication and their relationships to IT project success were investigated. The study did not include investigation of methodology selection and project staffing for complex IT projects, nor did it address the identification, selection, and appropriateness of specific IT project success criteria.

Nature of the Study

This study was intended to investigate relationships between IT project complexity, project complication, and project success. Beginning from a pragmatic perspective, the nature of the problem was considered in order to select an appropriate research design (Onwuegbuzie & Leech, 2005). A range of design options was considered, including qualitative case study, grounded theory, quantitative correlational analysis, and quantitative experimentation. A quantitative correlational design was selected with the intent of identifying project characteristics that were related to complexity, complication, and success. This approach offered the greatest likelihood of finding useful evidence of correlation without the methodological difficulties of attempting to establish causality. Although researchers have pointed out that IT projects and other individual complex adaptive systems do not tend to behave consistently with a quantitative, logical positivist paradigm (Brooks, 1995; Hass, 2009; Whitty & Maylor, 2009), a chaos theory perspective accepts the apparent paradox that while the behavior of individual population members may appear random and unpredictable, the behavior of populations is governed by principles which may be determined and measured (Lorenz, 1963).

The results of an extensive literature review indicated no existing models of project complexity distinguished between project characteristics tending to increase project complexity, and those tending to increase project complication. Existing models were analyzed to develop constructs and elements for these two variables. In addition, a definition of IT project success similar to that developed by the Standish Group (1994, 1999, 2009) was incorporated with minor modifications. Variables were operationalized, and an online survey was developed and hosted at SurveyMonkey. The survey was field tested and pilot tested prior to actual data collection.

The target population for the study was IT project management practitioners in the U.S. For purposes of availability and accessibility, the study population was limited to members of the former Project Management Institute Information Systems Special Interest Group (PMI-ISSIG), renamed during the course of the study to the Information Systems Community of Practice (IS CoP). The study population numbered approximately 6,000 individuals. For the purposes of this study, a 100% sample of all 6,000 members of the study population was used. With 235 qualified responses, post hoc power analysis with alpha α error probability = .05, correlation ρ = .30, and sample size of $n = 235$ indicated power (1-β error probability) = .9989.

The survey was pilot tested after IRB approval and prior to actual data collection. Participant access for pilot testing was obtained by posting a survey invitation to members of the PMI IS CoP (formerly PMI-ISSIG) LinkedIn group. With more than 6,800 members, a typical response rate to pilot study invitations of 3% was expected to yield more than 200 participants, a threshold historically considered desirable for survey pilot testing (Dillman, 2000); however, the actual number of responses ($N = 42$) exceeded the minimum of 35 to 40 participants that yields a confidence interval CI > 95% for hypothesis testing (Johanson & Brooks, 2010). Participant access for actual data collection was gained through e-mail invitations sent directly by PMI IS CoP. Participation was by invitation only with no capacity for referring or inviting other participants.

Data analysis included internal consistency testing with Cronbach's alpha, followed by tests of goodness of fit with the normal distribution including the Kolmogorov-Smirnov (Bryman & Cramer, 2005; Lehmann & Romano, 2005) and Shapiro-Wilk (Sen, 2002; Shapiro & Wilk, 1965) in order to confirm the ordinal data collected could be treated as interval data. Pearson correlation coefficients and Kendall's tau_b and Spearman's rho nonparametric correlations were then analyzed to determine the relationships between the study variables.

Organization of the Remainder of the Study

In Chapter 1, an introduction to the problem, the purpose and rationale of the study, and a summary of the research questions and study design have been provided. In Chapter 2, the literature of project management theory is reviewed from the perspective of organization theory and complex adaptive systems theory, and literature pertaining to sources of models of IT project complexity and definitions and factors affecting IT project success are reviewed and summarized. In Chapter 3, the research design, conceptual model, sampling, and data gathering strategies, data analysis methods, and validity and reliability considerations are presented. Chapter 4 contains a summary of the data collection process, data processing, and data analysis. In Chapter 5, the results of the study are summarized along with the study findings, conclusions, and recommendations.

CHAPTER 2. LITERATURE REVIEW

The purpose of this study was to investigate the relationship between information technology project complexity, project complication, and project success. In this chapter, a review of the literature pertaining to project complexity is provided, beginning with a summary of project management theory in the context of organizational paradigms from general systems theory. In addition to the rational, natural, and open systems views, a complex adaptive systems view was applied. Next, sources and models of IT project complexity are reviewed, distinguishing between project characteristics that tend to increase project complication and those that tend to cause IT projects to behave as complex adaptive systems. Finally, the literature on IT project success is reviewed, focusing on the distinction between project success and the criteria used to measure it, and the applicability of traditional definitions of project success to complex IT projects.

Theoretical/Conceptual Framework

In this study, a view of complex IT projects as complex adaptive systems, requiring different management methods, leadership, and definitions of success was applied. The complex adaptive systems view is based on a significantly different paradigm from traditional project management theory. This paradigm emerged from chaos and complexity theory and recognizes that interactions within and among complex adaptive systems are often nonlinear, emergent, and unpredictable. Such a paradigm can be seen as either conflicting with or complementing a positivist worldview (Morcol, 2001; Phelan, 2001). Although most existing project management theory is based on the rational systems view (Fayol, 1949/1919; March & Simon, 1958; Taylor, 1919), complexity theory and systems theory can be applied together (Phelan, 1999) to give a more complete view of complex projects. While some researchers have characterized multiple paradigms as an indication of immaturity (T. Kuhn, 1996), others have suggested they are normal and necessary in emerging fields (Lakatos, 1978; Phelan, 2001).

Conceptual Framework

Evaluating project management theory in the context of organizational paradigms from general systems theory, it is apparent that most existing schools of project management theory are based on the rational systems view. However, for projects with a high degree of complexity, the rational systems view is less appropriate and a paradigm incorporating the complex adaptive systems view is needed to describe the full range of project behavior (see Figure 3).

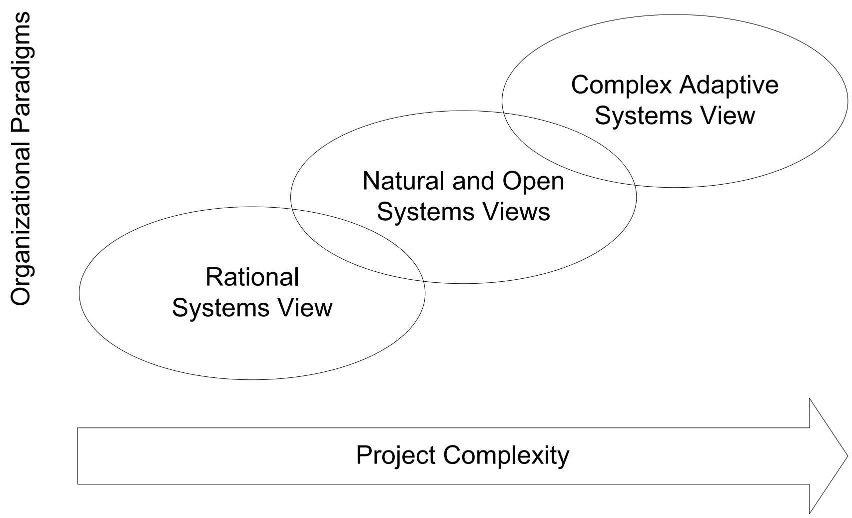


Figure 3. Conceptual framework combining project complexity and organizational paradigms.

Furthermore, project complexity may be distinguished from project complication (Cilliers, 1998). Project complication tends to result from extensive and detailed project requirements, long project duration, and large project team size (Cilliers, 1998; Hass, 2009). Project complexity tends to occur when requirements are unclear and changing rapidly, and the problem or opportunity is not clearly understood or defined (Baccarini, 1996; Jaafari, 2003; Whitty & Maylor, 2007). While existing models of project complexity do not differentiate explicitly between complexity and complication, these two sets of project characteristics have been found to have significantly different effects on project behavior and outcomes, suggesting they require different approaches to manage them effectively (Benbya & McKelvey, 2006; Xia & Lee, 2004).

The project complication and complexity (PCC) model developed for this study (see Figure 4) explicitly differentiated between IT project complexity and IT project complication, in order to investigate the relationship between them and their individual relationships with IT project success. Results confirmed that IT project complexity had a greater negative correlation with IT project success than did IT project complication.

Implications of such findings include greater focus in research and practice on identifying and managing project complexity differently from project complication, ultimately leading to greater likelihood of IT project success.

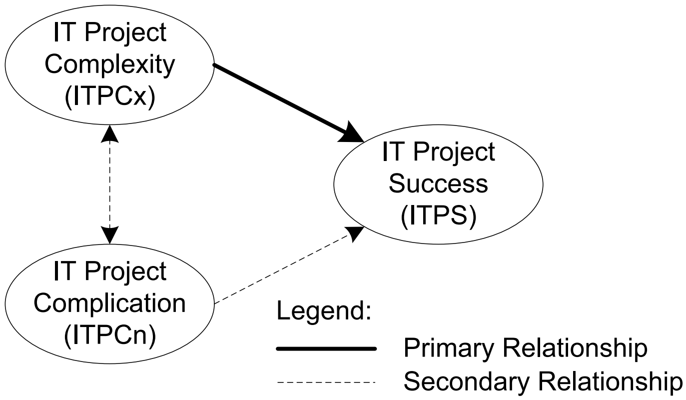


Figure 4. A project complexity and complication (PCC) model.

Project Management Theory

Project management is a cross-disciplinary, practitioner-oriented field with theoretical origins in a wide range of academic areas including operations research, systems theory, organizational behavior, management and leadership, marketing, finance, and law (Kerzner, 2006; Lewis, 2005; Project Management Institute, 2008a). As a result, some researchers have concluded there is little or no consistent underlying theory of project management (Betts & Lansley, 1995; Jugdev, 2004; Koskela & Howell, 2002). However, other researchers (Anbari, et al., 2008; Bredillet, 2007a, 2007b, 2007c, 2008a, 2008b, 2008c) have identified at least nine major schools of project management theory among numerous other theoretical perspectives including a social constructivist view (L. Crawford, 2006), trend analysis (Crawford, et al., 2006), project typologies and categories (Avison & Taylor, 1997; Evaristo & van Fenema, 1999; Shenhar & Wideman, 1997, 2002), the resource-based view (Jugdev, 2004), project actuality research (Cicmil, Williams, Thomas, & Hodgson, 2006), and organizational views (Shenhar & Dvir, 2007a). Researchers have suggested the wide range of management problems encountered in project management practice requires multiple theoretical bases (Shenhar

& Dvir, 2007a); one researcher further observed "the range of theoretical frameworks being applied in PM research and practice appears to be expanding" (Pollack, 2007, p. 272).

Researchers in newer, rapidly-evolving academic fields benefit from efforts to structure the existing body of knowledge, both to understand it better and to identify potential gaps in the literature for further study (Webster & Watson, 2002). Various frameworks have been applied to project management theory, including a historical timeline approach (Anbari, et al., 2008; Bredillet, 2007a, 2007b, 2007c, 2008a, 2008b, 2008c), project typologies and categories (Archibald & Voropaev, 2004; Avison & Taylor, 1997; Evaristo & van Fenema, 1999; Shenhar & Dvir, 1996; Shenhar & Wideman, 2002), management domains (D. K. Anderson & Merna, 2003), contingency theory (Shenhar, 2001), and the resource-based view (Jugdev, 2004).

In the first part of the literature review, the rational, natural, and open systems views of organization theory (Scott, 2003) were applied to project management theory. These three traditional systems view of organizations are complemented by the complex adaptive systems view (Buckley, 1968; Holland, 1992; R. Lewin, 1992), providing a framework for analyzing project management theory, including emerging theories of project complexity (Austin, et al., 2002; Baccarini, 1996; Cooke-Davies, Cicmil, Crawford, & Richardson, 2007; Fitzgerald & Bardyn, 2006; Hass, 2009; Singh & Singh, 2002).

Analyzing Project Management Theory

With its broad range of academic and practical origins, project management theory has been summarized and analyzed from multiple perspectives. Various approaches include historical timelines and trends (Anbari, et al., 2008; Bredillet, 2007a, 2007b, 2007c, 2008a, 2008b, 2008c), project categories and typologies (Archibald & Voropaev, 2004; Avison & Taylor, 1997; Evaristo & van Fenema, 1999; Shenhar & Dvir, 1996; Shenhar & Wideman, 2002), business domains (D. K. Anderson & Merna, 2003), contingency theory (Shenhar, 2001), and the resource-based view (Jugdev, 2004). This section reviews several approaches to analyzing project management theory, illustrating the opportunity for developing a comprehensive framework.

Historical trends. Anbari, Bredillet, and Turner (2008) and Bredillet (2007a, 2007b, 2007c, 2008a, 2008b, 2008c) applied a historical timeline approach to identify nine distinct schools of project management thought between the late 1940s and the early 2000s. The theoretical view they entitled the *optimization* school first emerged in the late 1940s and is most closely aligned with current understanding of mainstream project management theory and practice as advocated by the U.S.-based Project Management Institute (Project Management Institute, 2008a). Other schools including the *modeling*, *decision*, and *process* schools emerged later from the fields of systems theory, decision science, and information systems. The *behavior* and *marketing* schools are more closely aligned with organizational behavior and management theory. The *governance* school of project management theory applies a legal perspective, and the *success* school gathers perspectives on project success and failure.

Investigating the earlier historical origins of project management theory, Shenhar and Wideman (1996b) traced the practice of project management back to the commissioning of the earliest pyramids in Egypt by King Zoser to Imhotep. Shenhar and Wideman (1996b) then differentiated between the purposes, goals, and objectives of enterprises and projects and suggested that modern project management originated with the development of the generic project lifecycle.

Alternatively, Crawford (2006) applied a social constructionist view to the evolution of project management theory. Similar to other studies, she traced the origins of project management theory to the 1940s and 1950s with the emergence of network analysis and planning tools in the construction, engineering, defense, and aerospace industries. However, in her analysis, the 1960s to the mid-1990s represented a period of the growth of professionalism in project management. Beginning in the mid-1990s, the emphasis shifted to project management as a strategic organizational capability.

Separately, Crawford, Pollack, and England (2006) examined trends in the topics emphasized in project management literature over the period from 1994 to 2003, then compared them to trends identified in previous studies. Their list of topics incorporated a more detailed view than the larger schools of project management theory, but yielded similar results, showing a wide range of theoretical origins and practical applications. Comparing their own findings with the results of six prior studies, they concluded there is both a wide variety in the topics and themes represented, and a great deal of change in the topics of interest over the time periods studied.

While these analyses of the chronological evolution of project management theory are useful from a historical perspective, they incompletely assess the underlying theories and distinctions of the various theoretical schools. Attribution of the origins of various schools of project management theory to other academic fields and practices implies theoretical differences, but does not provide a comprehensive structure or framework for analyzing similarities, differences, overlaps, and gaps. Another approach utilized in the literature is the application of project categories and typologies.

Project categories and typologies. From the perspective of project characteristics, several researchers present the view that different types of projects require different project management methods. For example, Evaristo and van Fenema (1999) developed a typology of project management forms based on the number of simultaneous projects, their interdependencies, and their geographical dispersion. Shenhar and Wideman (1997, 2002) analyzed the type of work performed in a project and the type of product produced by the project to develop four categories of projects requiring different management approaches. In the same study, Shenhar and Wideman (1997, 2002) also proposed a project typology based on varying combinations of the project's technology content and scope. Avison and Taylor (1997) used an approach based on the problem situation to develop categories of projects suitable for various project methodologies. Archibald and Voropaev (2004) found existing project typologies and categorization schemes inadequate and suggested a more complete list of project categories was needed.

Some researchers have also suggested different project types require different criteria for project success. Applying the project categorization approach to the selection of project success criteria, Shenhar and Wideman (1996a) addressed the relationship between the degree of technological complexity exhibited by a project in the extent to which its success can be measured by internal, external, short-term, and long-term success criteria.

Analyzing and categorizing projects by their characteristics and using the resulting categories to suggest project management approaches and project success criteria benefits practitioners and scholars. The approach itself, however, also lacks an overall theoretical framework since, in most cases, the categories and distinctions are based on observed characteristics rather than a comprehensive model. Several other approaches based on theories from management disciplines have also been applied.

Other approaches to analyzing project management theory. Other approaches to the analysis, integration, and development of project management theory include management domains (D. K. Anderson & Merna, 2003), contingency domains (Shenhar, 2001), the resource-based view (Jugdev, 2004), adaptive control theory (Alleman, 2004), analytical decomposition (Koskela & Howell, 2002), actuality-based grounded theory (Cicmil, et al., 2006), and generic practices (Crawford & Pollack, 2007). Researchers have also suggested separate approaches for renewal projects (E. S. Anderson, 2006), central views and paradigms (Shenhar & Dvir, 2007a), and a critical research perspective (Cicmil & Hodgson, 2006).

Anderson and Merna (2003) constructed a list of 11 domains of project management and suggest that developing effective strategies for managing each domain would result in more effective project management. They critiqued their model in the context of four other groups of models: those based on process, knowledge, practice, and baselines. Essentially, their theoretical perspective was an extension of the optimization and modeling approaches.

Adding a contingency dimension, Shenhar (2001) elaborated on previous work (Shenhar & Dvir, 1996; Shenhar & Wideman, 1996b, 1997) to suggest different project management practices should be applied to projects with differing degrees of uncertainty and scope. He admitted, however, that uncertainty and scope are an incomplete set of contingency dimensions and may be supplanted in future research.

Jugdev (2004) explored the application of a resource-based view to the development of project management theory. She initially evaluated the applicability of project management maturity models but found they were largely anecdotal and empirically untested, and their emphasis was on project management processes rather than organizational processes, leading to a gap between operations and strategy. Focusing instead on project management as a strategic asset and competitive advantage, she concluded that much work remains in developing a comprehensive resource-based view of project management theory.

Alleman (2004) concluded that traditional project management practices are based on normal science with no consistent theoretical justification. Finding similarities between project management theory and adaptive control theory, he suggested abandoning an approach to project management based on incremental improvements to existing practices in favor of a new model based on emergent, agile methods.

Koskela and Howell (2002) drew different conclusions when they applied an analytical decomposition approach to the "underlying theory of project management" (p. 2). The theory of a project, they suggested, can be captured by the transformation view of operations, while management—consisting of planning, executing, and controlling—finds its theoretical basis in management-as-planning, classical communication theory, and the thermostat model. After combining these four theories as a foundation of project management theory, they admitted the approach was too narrow and needed further elaboration. Rather than the "paradigm change" (p. 3) they called for, their additions of flow and value generation to the project dimension, and management-as-organizing, the language/action perspective, and the scientific experimentation model to the management dimension represented incremental expansion of a limited model.

Cicmil et al. (2006) suggested that the actual experience of working on projects could not be simplified to such a great extent. Advocating an approach they called "project actuality research" (p. 675) and integrating components of the actors approach (Benson, 1977), they proposed a greater focus on the social processes within projects and the lived experience of project workers and project managers. Crawford and Pollack (2007) also questioned whether the practices of project management were generic enough to be applied consistently across projects in various industries and geographical locations.

Anderson (2006) pointed out that project classification schemes were rarely extended to develop distinct theories for different types of projects, and suggested that renewal projects, or those projects with a high degree of organizational change, required different project management approaches to be successful. Adopting a critical perspective, Cicmil and Hodgson (2006) suggested that existing theories of project management needed to be re-examined from a wider range of views including Marxist, feminist, environmentalist, and other postmodernist perspectives. Shenhar and Dvir (2007a) also suggested reviewing project management theory from different organizational views, including the strategic/business view, the team leadership view, and the operational/process view. Although a wide range of approaches has been applied to the analysis of project management theory, the field is still fragmented and in need of a comprehensive framework.

A need for new approaches. In spite of the wide variety of project management theory and approaches to analyze and model it, some researchers have expressed concern that traditional approaches to project management are increasingly unable to accommodate the challenges of complex projects (Geraldi, et al., 2008). Rather than converging toward a consensus regarding the best approaches for different types of projects, the field continues to grow more pluralistic and fragmented (Kolltveit, Karlsen, & Gronhaug, 2007). The need still exists for an overarching theory of project management broad enough to accommodate projects of different sizes, durations, degrees of complexity, geographic locations, industries, purposes, and risks (Williams, 1999).

Since projects are essentially temporary organizations (J. R. Turner & Muller, 2003), it may be suggested that many of the tools and perspectives of organization theory can be applied to projects. Adopting such an approach allows the full range of organization theory to be applied to project management theory. One such potentially useful theory is the organizational paradigms view derived from general systems theory.

Project Management Theory and Organization Theory

Widely recognized as a foundational theory of science (Boulding, 1956) and sociology (Von Bertalanffy, 1972), general systems theory has been extensively applied to the study of organizations (Katz & Kahn, 1966; Parsons, 1960; Scott, 2003; J. D. Thompson, 2003). As temporary organizations (J. R. Turner & Muller, 2003), projects can be viewed through the lens of general systems theory and organizational paradigms. Applying the systems paradigms from organizational theory to project management theory provides a framework for categorizing representative schools of project management theory according to their underlying assumptions and world views.

The rational, natural, and open systems views. From the early 1960s through the late 1990s, three systems views or paradigms of sociological structures and organizations—the rational, natural, and open systems views—were predominant. The rational systems view defined organizations as formal structures designed to accomplish specific goals. It emphasized the concepts of administration, authority, bureaucracy, hierarchy, efficiency, optimization, control, and performance (Blau, 1970, 1974; Blau & Schoenherr, 1971; Drucker, 1954; Fayol, 1949; March & Simon, 1958; Scott, 2003; H. A. Simon, 1947; Taylor, 1919; M. Weber, 1946, 1947, 1968). Conversely, the natural systems view recognized the existence of informal structures within organizations, each having multiple, simultaneous, and possibly conflicting goals. Rather than authority and control, the natural systems view examined conflict, cooperation, and consensus as the operative mechanisms in organizations (Barnard, 1938; Gouldner, 1954, 1959; Mayo, 1945; Scott, 2003; Selznick, 1948). The open systems view expanded this perspective to include interactions between organizations and their environments, and interdependence among their internal components and activities. In this view, greater attention was paid to processes, transactions, competition, alignment, flexibility, and contingency (Katz & Kahn, 1966; Lawrence & Lorsch, 1967; March & Simon, 1958; E. J. Miller & Rice, 1967; Scott, 2003; Selznick, 1948; Weick, 1979). Scott (2003) further refined the model by suggesting both closed and open subcategories of rational and natural systems views.

Even with their widely differing degrees of emphasis on organizational structure, formality, flexibility, and interactivity, all three traditional systems views applied an analytical, positivist, reductionist paradigm to the study of organization theory (Wheatley, 1992, 1999). Such a paradigm assumes organizations are best understood through decomposition and analysis of their individual parts and the relationships between them (Ashby, 1956; Scott, 2003). It also assumes organizations are generally *homeostatic* and seek to maintain a stable equilibrium (L. J. Henderson, 1935).

However, practitioners and researchers regularly encounter organizational and sociological systems which do not appear to fit any of the traditional analytical systems views. Cohen, March, and Olsen's (1972) study of decision-making within the "organized anarchies" (p. 1) of universities described a "garbage can model" of choice in organizations in which inconsistent decision-making criteria, unclear decision-making processes, permeable boundaries, and temporary membership required a "revised theory of management" (p. 2). Rittel and Webber (1973) described "wicked problems" (p. 1) in social systems which could be completely described, defined, or bounded, and which responded to attempted solutions with unintended and unpredicted consequences.

Addressing such problems of complexity and unpredictability at the societal level, Buckley (1967, 1968) suggested that sociological models based on analytical, reductionist paradigms and assumptions of equilibrium and homeostasis had "outlived their usefulness" (1968, p. 490) and proposed a fourth model of sociological systems initially entitled *sociocultural adaptive systems,* but now more generally known as the *complex adaptive systems* view.

The complex adaptive systems view. The complex adaptive systems view is more than an incremental extension to the rational, natural, and open systems typology. Because it recognizes complexity, or the tendency for the interactions within a system and among systems to be more significant than the component parts (Cilliers, 1998), it represents a paradigm change (T. Kuhn, 1996) or a worldview shift (Dent, 1999).

Complex adaptive systems have characteristics causing them to act differently from other systems. Rather than being planned and controlled, the interactions among the individual participants or components of complex adaptive systems exhibit the characteristics of emergence and autopoiesis or self-organization. This allows new and unpredicted organizational structures and patterns of behavior to emerge, which in turn remain relatively flexible and informal to accommodate continuous change. Their high degree of connectivity and interdependence with their environments and other systems means that their structures and rules of behavior need to be kept relatively simple, allowing and encouraging variety and ambiguity. In addition, complex adaptive systems are often particularly sensitive to small variations in their environments, and gravitate towards temporary balance between chaos and equilibrium rather than permanent stability (Buckley, 1968; Gleick, 1988; Hass, 2009; Holland, 1992; R. Lewin, 1992; J. H. Miller & Page, 2007; Mueller, 2004; Pines, 1998; Stoltz, 2004).

First defined to describe the behavior of living systems and organisms (Maturana & Varela, 1980), the complex adaptive systems view can also be applied to any system in which the interactions within and among the elements of the system and between the system and its environment cannot be separated, analyzed, and described independently—in other words, where the whole is greater than the sum of the parts—and where the tendency is for those interactions to change over time through the processes of learning and adaptation (Cilliers, 1998). Examples of complex adaptive systems relevant to this study include societies (Buckley, 1968), economies (Durlauf, 1997), communities (Stackman, Henderson, & Bloch, 2006), organizations (Thietart & Forgues, 1995), and projects (Jaafari, 2003).

Sociological entities as complex adaptive systems. Precedent exists in the literature for viewing sociological entities as complex adaptive systems (Eve, Horsfall, & Lee, 1997; L. Kuhn, 2007). Five years after Lorenz's (1963) seminal work on chaos and complexity in meteorology, Buckley (1968) suggested a revolutionary new view of societies as complex adaptive systems. Citing the absence of equilibrium or homeostasis in complex sociocultural systems, Buckley proposed a new paradigm he originally entitled the sociocultural adaptive system, but which is now more frequently referred to as the complex adaptive systems view of societies. In it, he described four salient characteristics of complex adaptive systems: (a) constant interaction with their external environment; (b) variety and adaptation; (c) selection; and (d) preservation and propagation. Interaction, adaptation, and selection were the characteristics he cited that differentiate complex adaptive systems from rational, natural, and open systems; preservation and propagation allow complex adaptive systems to survive and persist.

Further extending the complex adaptive systems view to markets and economies, Durlauf (1997) and Arthur, Durlauf, and Lane (1997) distinguished between problems that are "'complicated' or 'hard to analyze or solve'" (p. 157), and those that are actually complex by emphasizing in the latter the emergence of unpredicted forms of order resulting from interactions between large numbers of subsystems and participants. As a result, they concluded that traditional economic theory did not adequately describe the behavior and interactions of complex economic systems.

Applying complex adaptive systems theory to communities, Stackman, Henderson, and Bloch (2006) expanded its definition to include the characteristics of autopoiesis, fractals, and phase transitions. They defined autopoiesis as self-organization, or the ability to adapt to environmental changes without external control. They invoked fractals, familiar from the works of Lorenz (1993) and Mandelbrot (1977, 1982), to describe the tendency for communities to repeat organizational patterns at different scales, and they applied the concept of phase transitions to describe the tendency of communities to undergo frequent transitions between periods of relative order and disorder or chaos. The work of Alexander (1979) in the field of architecture has also addressed the adaptive nature of communities.

Organizations as complex adaptive systems. As sociocultural entities created for the purpose of achieving goals (Blau & Scott, 1962), organizations can also be viewed as complex adaptive systems. Etzioni (1961) used a complex adaptive systems approach to analyze the issues of control and compliance in the literature about complex organizations, and developed a model for integrating social environment and compliance structures. Hannan and Freeman (1989) applied complexity theory to develop an approach relating organizations to ecological systems in response to perceived inadequacies in current organizational theory. Thietart and Forgues (1995) recognized instability and rapid change as normal features of organizations they described as "nonlinear dynamic systems subject to forces of stability and instability which push them toward chaos" (p. 19). Considering the effects of environmental and organizational chaos, Thietart and Forgues encouraged the field of organization science to integrate a model of organizations as complex adaptive systems.

Schein (1990, 1996) addressed similar deficiencies in contemporary organization theory by suggesting the field pays inadequate attention to social systems and interactions in organizations. Culture, as Schein described it, corresponds well with the complex adaptive systems characteristics of interdependency, emergence, and self-organization. Seel (1999) also focused on the organizational theory perspective, drawing an analogy between studying organizations with normal science and searching for one's keys under a lamppost to suggest that complex adaptive systems theory allows seeing organizations as more than simple, linear systems.

A.Y. Lewin, introducing a special issue of the journal *Organization Science*, stated "The implications of complexity for informing research in organization science are immediate and reveal pressing conceptual and methodological challenges" (1999, p. 215). Boisot and Child (1999) adapted a complex adaptive systems approach to a case study analysis of three Chinese organizations, concluding that organizations must adapt to their complex environments. Morel and Ramanujam (1999) also recommended extending organization theory to accommodate advances in complex systems theory, agreeing that an evolutionary view of organizational change was more appropriate than one which assumed predictability and controllability.

Dolan, Garcia, and Auerbach (2003) continued to build the case for a complex adaptive systems view of organizations and suggested the appropriate paradigm for organizations in the 21st century was one which accommodated turbulence or rapid, extreme change. Only *management by values* was agile enough to accomplish this, they theorized, while *management by objectives* and *management by instruction* were structurally incapable of adapting rapidly enough to accommodate complexity and continuous change. Also citing the adaptive nature of complex systems, Desai (2005) emphasized the need for robust information systems in complex enterprises, positioning information as both raw material and organizing structure in complex organizations.

Caroll (2002) examined the information processing challenges of modern organizations trying to accelerate business processes by seeking an optimal balance between interdependence and speed, concluding through the application of complexity theory that less structure and interdependence improved task performance.

Other related applications of complex adaptive systems theory include a model of organizational change (Dooley, 1997), management approaches designed specifically for complex organizations (K. Richardson, 2008), strategies for accommodating continuous change in organizations (S. L. Brown & Eisenhardt, 1997), and recommendations for improving enterprise agility (Overby, Bharadwaj, & Sambamurthy, 2006). Researchers have also applied chaos and complexity theory to topics including strategy (Levy, 1994), leadership (Schneider & Somers, 2006), marketing (Doherty & Delener, 2001), software development (Hassan & Holt, 2003; Muffato & Faldani, 2003; Reddy, 2006), and information systems management (Benbya & McKelvey, 2006; Boisot, 2006; McBride, 2005). Project management applications included general project management (Ivory & Alderman, 2005; Liu, Sun, & Tan, 2006; Thomas, Mengel, & Andrès, 2004) and project management in technology (Philbin, 2008), telecommunications (Bardyn & Fitzgerald, 1996; Fitzgerald & Bardyn, 2006), information technology (Glass, 2006a; Ko, et al., 2006; Royal Academy of Engineering & British Computer Society, 2004), outsourcing (Garrett, 2003; Ko, et al., 2006), and commercial construction (G. S. Griffin, 1996).

Projects as complex adaptive systems. One of the earliest articles discussing projects as complex adaptive systems was Bardyn and Fitzgerald's (1996) first-hand case study and analysis of a large systems deployment project at NYNEX in which they candidly admitted the difficulties they faced in undertaking a complex, high risk project in an organization operating under the rational systems paradigm. Recognizing the ineffectiveness of a project management approach based on planning and control, they instead focused on creating temporary conditions of stability to serve as platforms from which to maximize learning and change. They also expanded and amplified feedback mechanisms, and encouraged continuous evolution of project structure and processes. Even though the project appeared to be failing in the early stages, and progressed very differently from initial plans, the authors attributed its ultimate success to the adoption of a complex adaptive systems approach.

Highsmith and Cockburn (2001) suggested that agile software development methods, based on a complex adaptive systems view of organizations and software development projects, were more effective in accommodating changing requirements and changing organizations. Harkema (2003) applied a complex adaptive systems view to learning in innovation projects, suggesting that organizational learning in a complex project environment was enhanced by fewer controls and less structure.

Several decades after it was first applied to sociological analysis (Buckley, 1968), complex adaptive systems theory has not made its way into general project management practice. Jaafari (2003) cited the continuing rapid evolution of complexity theory itself as one possible explanation for the lack of practical application. The field may benefit from a greater emphasis on the integration of general systems theory and organization theory with project management theory.

Applying Organization Theory to Project Management Theory

Box (1979, p. 202) is frequently cited for his observation that "all models are wrong, some [models] are useful." The organizational paradigms model from general systems theory, including the rational, natural, open, and complex adaptive systems views, constitutes a model that is abstracted and simplified, but useful. The theoretical origins, principles, and areas of emphasis of various schools of project management theory can be analyzed from the perspective of general systems theory in order to determine their underlying organizational paradigms, providing potential insight into their theoretical and practical compatibility with complex projects. The following sections review representative schools of project management theory to determine the paradigm with which they are best aligned. Following this analysis, a summary concludes current project management theory is still predominantly based on the rational systems paradigm.

Optimization and decision science. The optimization school of project management theory, as defined by Anbari, Bredillet, and Turner (2008) and Bredillet (2007a, 2007b, 2007c, 2008a, 2008b, 2008c) is founded on operations research and views projects as machines with linear, predictable inputs and outputs. Decomposition of project objectives into a *work breakdown structure* is accompanied by detailed estimation, budgeting, scheduling, tracking, and control (Kerzner, 2006). The emphasis on formal rules, hierarchy, efficiency, and performance in the optimization school indicates it is most closely aligned with the rational systems view. In addition, this view of projects, methods, and approaches has been popularized by professional organizations to the extent that it is the predominant school of project management theory and practice in the U.S. and the U.K. (Association for Project Management, 2006; Project Management Institute, 2008a).

The decision (Anbari, et al., 2008) or decision science school of project management theory incorporated information as a project input and expanded the scope of concern to include elements of the project's social, political, and economic environment (Ives, 2005), but still emphasized predictability and control as predominant project characteristics. Accordingly, it can be characterized as an *open* rational systems view (Scott, 2003).

Process and modeling. Anbari, et al. (2008) and Crawford and Pollack (2004) described both hard and soft systems components of the modeling school of project management theory, with the hard systems component evolving from the optimization school and the soft systems component expanding to incorporate more aspects of the project environment. Wideman (2003) also advocated a modeling approach to improve understanding and execution in project management. The hard systems component of the modeling school, even with its broader perspective on optimizing multiple project dimensions simultaneously, is a rational systems view. The soft systems component, with its emphasis on the project environment, is best characterized as an open natural systems view.

Rather than a completely separate school as suggested by Anbari, et al. (2008), the process school can be viewed as a further expansion of the hard and soft systems modeling schools. Its hard dimensions have included optimizing project processes, while its soft dimensions have focused on selecting the appropriate processes for different project types and environmental conditions. Similar in this aspect to the contingency school (Lawrence & Lorsch, 1967; Shenhar, 2001), the process school can be categorized as primarily based on an open rational systems view.

Project success. Applying an empirical approach to cataloging what works in practice, the project success school has investigated characteristics of successful and unsuccessful projects in an attempt to generalize to the practice as a whole. Verner, Overmyer, and McCain (1999) reflected on lessons learned since the publication of Brooks' (1975) classic work on software project management to identify critical success factors. Several authors have expanded the approach with a systems view (Fortune & White, 2006), agile project management practices (Cao, 2006; Chin, 2004), subjective evaluation factors (Wohlin & von Mayrhauser, 2000), case study and grounded theory (Cooke-Davies, 2002; Henry, 2004; J. Johnson, 2006; Yardley, 2002), contingency theory (Dvir, Lipovetshy, Shenhar, & Tishler, 1998; Royce, 2005), cultural aspects (Kendra & Taplin, 2004), information systems planning (Peffers, Gengler, & Tuunanen, 2003), and prescriptive approaches (Henry, 2004; M. D. Lewin, 2002; Young, 2000), adding to a significant body of literature focused on identifying practices that lead to project success. The constructivist nature of this type of investigation indicates that the project success school is most closely aligned with an open natural systems view.

Behavioral school. The behavioral school of project management theory has derived most of its underlying theory from organizational behavior. Focus on social dimensions (Cicmil, 2006), leadership (J. Turner & Muller, 2005), conflict management (A. G. J. Butler, 1973), and power and politics (Pinto, 1996) typify this school and reveal its roots in an open natural systems view. Theory W Software Project Management (Boehm & Ross, 1988) is an extreme version of this view, where an attempt is made to simplify principles and processes by applying a win-win philosophy as the overriding objective. A related study by Gillard (2004) also compared the tri-dimensional nature of relationships within complex project-based organizations to more typical matrix organizations.

Marketing and stakeholder management. The marketing and stakeholder management schools of project management theory have emphasized customer relationship management (Frame, 1995), communication, stakeholder identification and management (Fowler & Gilfillan, 2003; Freeman, 1994), and business strategy (D. K. Anderson & Merna, 2003; E. S. Anderson, 2006). Their emphasis on boundary-spanning activities is indicative of their origins in an open natural systems view.

Alignment with business strategy. Closely related to the marketing and stakeholder management schools, a large and growing body of literature addresses the alignment of project strategy with business strategy (Milosevic & Srivannaboon, 2006; Srivannaboon & Milosevic, 2006). Particularly in the information technology field, alignment has been researched extensively (J. Henderson & Venkatraman, 1996; Luftman, 2003; Milosevic & Srivannaboon, 2006; Sabherwal & Chan, 2001; Sledgianowski & Luftman, 2005; Srivannaboon, 2005; Teo & King, 1997; Van Der Zee & DeJong, 1999). Business focused project management (Comninos & Frigenti, 2002) can be viewed as a simplified approach to alignment. The boundary-spanning perspective combined with emphasis on internal measures of effectiveness, efficiency, authority, and performance indicate the alignment school is most closely related to an open rational systems view.

Contingency theory. The contingency school of project management theory has focused on determining different types of projects and selecting appropriate processes (Crawford & Pollack, 2007; Shenhar, 2001). Founded on Vroom and Yetton's (1973) research into decision processes and the work of Lawrence and Lorsch (1967) the contingency-based view of projects is most closely aligned with an open rational systems view.

Project complexity. Issues exist with all of these schools of project management theory. Consensus is developing that a new approach to project management theory and practice is needed. Leybourne and Sadler-Smith (2006) cited the lack of research into the role of intuition and improvisation in project management success. Suggesting that intuitive decision-making and improvisation have always been an important component of project success, they called for increased emphasis on the use of unstructured methods. Winter, et al. (2006) and Sauer and Reich (2009) called, respectively, for a rethinking of project management in general and IT project management specifically. Saynisch (2005) advocated going beyond the limitations of traditional project management methods, and Geraldi, et al. (2008) suggested the need is growing for a complexity view of project management.

Agile project management (Neudorf, 2008) and extreme project management (D. DeCarlo, 2004, 2005, 2007) are initial forays into this area. Agile project management, including emerging methodologies such as evolutionary project management (Gilb, 2007; Larman, 2004) and SCRUM has evolved from the agile software development movement (Agile Alliance, 2001; Alleman, 2005; Chin, 2004; Fernandez & Fernandez, 2009; Highsmith, 2004; Koskela & Howell, 2002; Schwaber, 2007; Sutherland, 2005). DeCarlo's "eXtreme" project management specifically addressed volatility as a driving factor for projects that required (a) accepting chaos, (b) managing unknowns, (c) planning just-in-time, and (d) acting quickly and innovatively (D. DeCarlo, 2004, 2005).

These approaches are part of a larger, emerging school of project management theory based on elements of the complex adaptive systems view. First discussed in the architecture, engineering, and construction industries (Austin, et al., 2002; Baccarini, 1996; G. S. Griffin, 1996), it has since been applied to new product development projects and organizational culture change (Belassi, 1999; Belassi, Kondra, & Tukel, 2007), telecommunications (Bardyn & Fitzgerald, 1996, n.d.; Fitzgerald & Bardyn, 2006), and information technology (Benbya & McKelvey, 2006; Glass, 2006a; Ko, et al., 2006; Xia & Lee, 2005).

Project Management Theory and the Systems View

As temporary, interactive organizations, projects can be described as rational, natural, or open systems (Boulding, 1956; Churchman, 1968; Von Bertalanffy, 1972). Depending on the interconnectedness of their component parts, the degree to which they address unknowns, and the extent to which they interact with their environments (Churchman, 1967; Rittel & Webber, 1973), projects can also exhibit the characteristics of complex adaptive systems (Buckley, 1968). However, prevailing schools of project management theory (see Table 1) are still predominantly based on the rational systems view (Fayol, 1949/1919; March & Simon, 1958; Taylor, 1919).

Table 1

Schools of Project Management Theory and their Systems Views

Period	School	Systems view
1940s	Optimization	Rational (Closed)
1950s – 1960s	Modeling: Hard Systems	Rational (Closed)
1970s	Behavior	Natural (Open)
	Governance	Natural (Open)
1980s	Decision	Rational (Open)
	Process	Rational (Open)
	Success	Natural (Open)
	Theory W	Natural (Open)
1990s	Contingency	Rational (Open)
	Marketing	Natural (Open)
	Modeling: Soft Systems	Rational (Open)
	Standardization	Rational (Closed)
2000s	Agile/Extreme	Complex Adaptive
	Alignment	Rational (Open)
	Business-Focused	Rational (Open)
	Complexity	Complex adaptive
	Project Management Maturity	Rational (Closed)

The emerging school of project complexity, based on the complex adaptive systems view and complexity science provides a broader, more appropriate theoretical foundation and a wider set of project management methods and approaches for accommodating projects of increasing complexity. Information technology projects, due to their inherent characteristics, tend to be highly complex. In the following section, the literature pertaining to IT project complexity is reviewed.

Information Technology Project Complexity

In the 20th anniversary edition of his seminal work on software development management, Brooks (1995) conceded "complexity is the business we are in, and complexity is what limits us" (p. 226). Many projects are *complicated*. Large projects in the construction, engineering, defense, and aerospace industries often have millions of separate parts and components. According to one estimate, the Space Shuttle has 2.5 million parts (Popular Mechanics, 2006), but even that number increases or decreases depending on how sub-systems are divided and aggregated (NASA, 2006). However, it is not the sheer number of parts, sub-systems, or even participants that make a project or a system *complex* (Cilliers, 1998).

Complexity is a characteristic of systems whereby the interactions among the parts of the system and between the system and its environment cannot be isolated, analyzed, and understood separately from the system as a whole; furthermore, these interactions tend to change over time as the system adapts to changes in the internal and external environment and exerts influence on its environment and other systems, in turn causing them to change (Buckley, 1968; Gleick, 1988; Hass, 2009; Holland, 1992; R. Lewin, 1992; J. H. Miller & Page, 2007; Mueller, 2004; Pines, 1998; Stoltz, 2004). The iterative nature of this adaptive process leads to the emergence of unpredicted structures and behaviors (Maturana & Varela, 1980). Several researchers (Austin, et al., 2002; Baccarini, 1996; Bardyn & Fitzgerald, 1996; Brockhoff, 2006; Cooke-Davies, et al., 2007; Fitzgerald & Bardyn, 2006; Frame, 1994; Jaafari, 2003; Singh & Singh, 2002; Whitty & Maylor, 2007) have agreed that complexity in projects tends to occur when:

1. The problem or opportunity is not clearly defined.
2. There are a large number of unknowns.
3. The requirements are unclear and volatile.
4. The outcome is unpredictable.
5. The project schedule is over-ambitious or over-constrained.
6. The project uses or creates new technology.
7. There is a rapid rate of technological change.
8. There are significant political and social influences.
9. There are critical external dependencies and constraints.
10. The project itself creates significant change.

While some models of project complexity (Hass, 2009; Sauser, Reilly, & Shenhar, 2009; Shenhar & Dvir, 2007b) have included characteristics such as cost, duration, team size, and team experience, it is useful to distinguish between project characteristics that cause project complexity, and those that increase the difficulty of managing complex projects by making them more complicated (Arthur, et al., 1997; Cilliers, 1998; Durlauf, 1997). Projects tend to be more complicated when (Cilliers, 1998; Hass, 2009):

1. The project cost is high.
2. The project duration is long.
3. The project team is large and/or geographically dispersed.
4. The project team lacks experience with the project content or technology.

Differentiating between project complexity and project complication in this manner allows a more specific focus on the sources of IT project complexity.

Sources of IT Project Complexity

Information technology projects tend to be both complex and complicated. Software development is one of the most difficult activities undertaken by humans (Brooks, 1975; McConnell, 1996), and IT projects are made more difficult by the inherent characteristics of software and information technology, and by the organizational and environmental change that often accompanies them.

Software projects are particularly difficult because software is abstract, intangible, and invisible (Hassan & Holt, 2003; McDonald, 2001). Rather than creating physical products, they are intended to capture and systematize abstract encapsulations of unique information management processes (Tiwana & Keil, 2004; Xu & Ramesh, 2003). Software has the potential for almost infinite connectivity, making it more analogous with quantum physics than with Newtonian physics (Dent, 1999; Wheatley, 1999). This, in turn, necessitates a paradigm shift (T. Kuhn, 1996) in order to understand and manage complex software projects more effectively (Filman, 2005). Hardware components of IT also evolve rapidly. Moore's Law, first postulated in 1965 and confirmed for more than 40 years (Intel, 2005), predicted that the maximum number of transistors on a single chip would double every two years. The combination of intangibility and invisibility of software and rapid evolution of hardware and other enabling technologies has contributed to the high degree of inherent complexity in information technology projects.

Factors contributing to IT project complexity have been analyzed both qualitatively and quantitatively. Boisot (2006) applied an information complexity view to develop a conceptual framework for evaluating knowledge flow in organizations, suggesting that IT became more complex as institutions and the information they contain moved from concrete to abstract, codified to uncodified, and undiffused to diffused. Sauer and Cuthbertson (2003) reported on a large descriptive study of 1,500 IT project management practitioners in the U.K., finding a wide range of factors contributed to project complexity including organizational, authority, control, staffing, and alignment issues. Another U.K. study (B. R. R. Butler, et al., 2004) identified the abstract nature of software as a significant contributing factor to project complexity; regarding the same study, however, Glass (2006a) cited low levels of professionalism and education, as well as inadequate understanding of project management practices.

Fenton and Ohlsson (2000) also found that neither software size nor traditional software complexity measures fully explained software complexity or the likelihood of software component failure. In a quantitative study of two consecutive releases of a large telecommunications software application, they did not find significant correlations between software module size as measured in lines of code, or software complexity as measured by cyclomatic complexity measures, and subsequent probability of software component failures and faults. In their conclusions, they suggested other process-related factors such as methodology and testing effort, and other dimensions of complexity may contribute more to software component failure.

Perception and Measurement of IT Project Complexity

Information technology project complexity can be both experientially perceived and quantitatively measured. The perception of project complexity is subjectively experienced by the project manager, project team, and other project stakeholders.

Rakhman and Zhang (2008) applied qualitative and quantitative analysis to case studies from Chinese and Indonesian manufacturing firms and determined the perception of project complexity varied widely with project manager experience. While project managers typically were not able to describe project complexity in terms of the characteristics of complex adaptive systems, the researchers found a positive correlation between projects exhibiting these characteristics and the likelihood their project managers perceived them as complex. In practice, actual IT project complexity has been underestimated (Daniel, 2007).

Xia and Lee (2005) assessed the complexity of information systems development projects (ISDPs) along two axes: one incorporating organizational and technological complexity, and the other incorporating structural and dynamic complexity. Using survey data collected from 541 North American IS project managers belonging to the PMI IS-SIG, they applied *p*-values and chi-square tests to evaluate goodness-of-fit of the 15 factors and four constructs in their first-order project complexity model, and confirmatory factor analysis and the target coefficient (T) to determine validity of the four constructs in their second-order model. Both models had significant chi-square results indicating possible effects of the relatively large sample size ($N = 541$) on goodness of fit; however, a high T coefficient of 0.94 between the first-order model and the second-order model confirmed that the 15 factors and four constructs adequately measured IS development project complexity.

IT Project Complexity and Project Risk

Project complexity and project risk have also been found to be closely related (Jiang, et al., 2002). Many models measuring IT project risk have actually measured aspects of project complexity and project complication. Tesch, Kloppenborg, and Frolick (2007) performed an extensive literature review and identified 33 components of software project risk. Several factors they described—including the introduction of new technology, unclear and rapidly changing requirements, lack of commitment and leadership, and the role of organizational conflict—indicated similarities between project risk factors and project characteristics contributing to project complexity.

Jiang et al. (2002) investigated quantitative measurements of software project risk among IS project managers by surveying a sample of 152 PMI members in the U.S. They constructed and pilot-tested a model based on a simplified version of a prior instrument (Barki, Rivard, & Talbot, 1993), then performed confirmatory factor analysis and goodness-of-fit testing on the survey data with chi-square/degrees of freedom $\chi^2/df =$ 1.41 and 1.5 respectively for the first-order and second-order models, indicating a good fit between the survey data and their updated model. Findings included that the complexity of the application itself and the underlying technology, coupled with extensive and rapid change, and exacerbated by unclear requirements, greatly increased the risk of a software development project.

Project complexity and information overload also affected which projects were selected for risk reviews. Pennington and Tuttle (2007) performed an experiment among IS auditors belonging to the Information Systems Audit and Control Association (ISACA) to assess the likelihood that IT projects were selected for in-depth review when high degrees of project complexity were further obfuscated by information overload. Simulating a project assessment process under conditions of time pressure versus unlimited time, they found that IT managers were less able to discern potential risk factors under conditions of information overload.

Project risk and its relationship to project complexity have also been applied to a special category of projects focused on software process improvement (SPI). Accordingly, risks for SPI have been found to correlate with general risks for software development. Statz, et al. (1997) compiled 63 risk factors from SPI projects performed for U.S. military organizations by reviewing documentation from capability maturity improvement reports. The researchers' evaluation of the severity of the risk factors from their project experience suggested that organizational factors such as SPI staff, project management, and organization culture and management contributed the greatest risk to SPI projects. Since SPI projects are essentially software projects targeted at processes for managing software projects, they tend to be particularly risky and complex. Stelzer and Mellis (1999) analyzed reports and case studies of 56 organizations that undertook software quality or capability maturity SPI efforts to determine the most significant factors for project success. Management commitment and staff involvement were cited in 91% and 84% of the cases, respectively, confirming the similarities between risk factors for SPI projects and other forms of software projects. Wallace, Keil, and Rai (2004) surveyed 507 PMI-ISSIG members and performed quantitative cluster analysis to determine factors contributing to software project risk. Of the six risk dimensions evaluated, complexity was found to be the most consistent contributing factor to project risk.

Project complexity and complication increase IT project risk (Tesch, et al., 2007; Wallace, et al., 2004), and many existing models of project risk have incorporated dimensions of project complexity (Jiang, et al., 2002). However, complexity affects project execution and success differently because it influences the nature of project interactions (Brooks, 1995; Filman, 2005). Characteristics of information technology which tend to increase IT project complexity include (Hass, 2009; Sauer & Cuthbertson, 2003):

1. Technology change
2. Organizational change
3. Requirements ambiguity and change
4. External dependencies and constraints
5. Political and strategic influences

Similarities between project complexity and project risk have been found in other industries as well. Datta and Mukherjee (2001) categorized risks on industrial projects into internal and external factors, with internal factors relating to project size and complexity as well as the project governance structure, including contract type and the role of external agencies and outside contractors, and external factors relating to technological change and economic, political, and social environments. Case study of two industrial plant upgrades in India confirmed the relationship between project characteristics associated with complexity and project risk.

Models of Project Complexity

Recent literature describes the emergence of several models of project complexity. Models incorporating a partial set of complexity criteria or targeted at specific project types or industries include Xia and Lee's (2004, 2005) ISDP complexity model, and a model based on new product development projects (Kim & Wilemon, 2003, 2009). The evolution of models considering combinations of uncertainty, complexity, and project pace, which first began at NASA, has recently been extended to the field as a whole (Sauser, et al., 2009; Shenhar & Dvir, 2007b). The project complexity model developed by Hass (2007a, 2007b, 2009) is the most comprehensive at this time, but remains untested by empirical means. The remainder of this section assesses several of these models.

Partial models. Focusing on new product development (NPD) projects, Kim and Wilemon (2003, 2009) constructed a matrix of complexity sources related to key functional areas. Sources included technological, market, development, marketing, and organizational and inter-organizational complexity. Functional areas studied included R&D, engineering, manufacturing, and marketing. Each intersection of the matrix was scored with a quantitative assessment of complexity and an overall project complexity score was then determined. While useful for assessing the potential importance, frequency, and number of interactions among organizational components, their model applied a rational systems view and an analytical, reductionist paradigm, focusing primarily on the number and nature of the tasks and subtasks and the quantity of internal interactions, rather than the nature of those interactions.

The information systems development project (ISDP) complexity model developed by Xia and Lee (2004, 2005) considered two primary dimensions of project complexity. Emphasizing environmental characteristics, the researchers first differentiated between project characteristics associated with organizational structure and those related to technological environment and infrastructure. Next, they distinguished between structural and dynamic complexity, or the complexity associated with the existing environment as well as the degree to which the environment changes. The resulting model of four types of IT project complexity was then tested with survey data collected from 541 ISDP project managers belonging to the PMI-ISSIG. Consistent with other investigations into the nature of project complexity, Xia and Lee found that while structural IT complexity was rated highest by surveyed ISDP managers with a mean score of $M = 5.03$ on a 7-point Likert-type scale, it had no significant correlation to project performance. Structural organization complexity, conversely, with a mean score of only $M = 3.40$ but regression coefficients ranging from $r^2 = -.311$ to $-.395$, $p < .01$, with four measures of project performance, had the largest impact on overall project execution. Factors contributing to structural organizational complexity included control over project resources, user support, project resource availability, and project team skills. Factors contributing to dynamic organizational complexity included the impact of the project on existing business processes, rapid change in user requirements and existing business processes, changes in organizational structure, and changes in the IT infrastructure, architecture, and toolset.

The Novelty-Technology-Complexity-Pace (NTCP) model. Evolved from the NASA Uncertainty-Complexity-Pace (UCP) model (Shenhar, et al., 2005) and incorporating the *novelty* dimension of projects (Brockhoff, 2006), the Novelty-Technology-Complexity-Pace (NTCP) model (Sauser, et al., 2009; Shenhar & Dvir, 2007b) provided a comprehensive view of project complexity. Derived from their work on contingency approaches to project classification and methodology selection, the NCTP model synthesized their findings regarding classification criteria. Four primary dimensions of project complexity were assessed with project data gathered from NASA archives. The *novelty* dimension considered the degree of newness exhibited by the project's end product. The *technology* dimension considered the degree to which new technology was used in the product and the product itself. The *complexity* dimension incorporated the environmental interaction characteristics of complex systems, measuring the degree to which the project interacted with other projects and where it fit within a hierarchy of other projects and subprojects. Finally, the *pace* dimension assessed urgency and the schedule duration. Together, these four dimensions were represented graphically in a diamond configuration, providing both a quantitative measure and a visual representation of project complexity. For each of the four NTCP dimensions, a three or four point scalar range of complexity was developed by analyzing the conditions encountered in four significant NASA projects. Some of the dimensions combined aspects of both project complication and project complexity. For example, the inclusion of technology itself was found to have less of an influence on project complexity than did the degree to which the technology was changing. Also, the relative position of the project on a hierarchy of systems and subsystems contributed to project complexity not by the sheer number of individual components, but rather by the extent of interdependencies between systems. The NTCP model provides a concise screening tool for determining a project's relative complexity, albeit specifically structured for conditions encountered on large projects at NASA. The Hass (2007a, 2007b, 2009) project complexity model incorporates a more detailed examination of a wider range of complexity factors.

The project complexity model. Hass (2007a, 2007b, 2009) developed a comprehensive project complexity model (PCM) and then described its implications for project staffing, project lifecycle selection, and project management practices. The model was based on the NTCP model and Hass' experience as an educator and practitioner. Hass suggested 11 categories of project complexity dimensions and three degrees of complexity for each, ranging from small, independent projects to large, highly complex projects. Some of Hass' complexity dimensions were conceptually simple, such as project duration and cost and team size, while others such as team composition, and risks and dependencies, incorporated multiple contributing factors. Hass' (2009) complexity dimensions included:

1. Time/cost
2. Team size
3. Team composition and performance
4. Urgency and flexibility of cost, time, and scope
5. Clarity of problem, opportunity, and solution
6. Requirements volatility and risk
7. Strategic importance, political implications, multiple stakeholders
8. Level of organizational change
9. Level of commercial change
10. Risks, dependencies, and external constraints
11. Level of IT complexity

These factors can be analyzed in the context of other studies of contributing factors to project complexity construct a comprehensive list of project complexity factors. Although it has not previously been evaluated empirically, the Hass (Hass, 2007a, 2007b, 2009) project complexity model is the most comprehensive model reviewed. Several of the dimensions, however, combine factors contributing to project complication with those contributing to project complexity. Differentiating between these factors distinguishes the potential underlying causes of project complexity from factors that can make any project more complicated.

Project Complexity and Project Complication

The Hass (2007a, 2007b, 2009) project complexity model, the NTCP model (Sauser, et al., 2009; Shenhar & Dvir, 2007b), and other models of project complexity (Kim & Wilemon, 2009; Xia & Lee, 2004, 2005) have offered differing perspectives and degrees of detail on the underlying dimensions and factors contributing to project complexity. None of the models has distinguished explicitly between project complexity and project complication; however, Xia and Lee's consideration of dynamic and structural dimensions to complexity partially addressed the nature of the interactions between a project and its environment. Project complexity, based on the characteristics of complex adaptive systems, occurs when interactions within the project and with its external environment take on the characteristics of complexity and adaptivity. Project complication is increased when the number of participants or components increases, the budget becomes larger, or the schedule becomes longer. Consistent with chaos and complexity theory, the impact of project complication on project difficulty and performance is linear, while the impact of project complexity is nonlinear and unpredictable (see Table 2).

Table 2

Causes and Effects of Project Complication and Project Complexity

	Project complication	Project complexity
Causes	Large number of individual components Long project duration Extensive, detailed project requirements Large project team Inexperienced project team	Nonlinear interactions between components Technological and organizational change Ambiguous or unknown objectives Ambiguous or unknown project requirements Unrealistic schedule compression External interactions, dependencies, and constraints Strong political and strategic influences
Effects	Project execution is more detailed and time-consuming Project risk is increased Project cost is higher	Project behavior attempts to adapt to environment, new forms emerge Project risk is significantly increased Project schedule, cost, and outcomes are unpredictable

Information Technology Project Success

Information technology project success is less common than failure (J. Johnson, 2006; Standish Group, 1994, 1999, 2001a, 2001b, 2007, 2008, 2009). In this section, the symptoms and causes of IT project failure are reviewed in order to summarize both the characteristics of projects that tend to lead to project failure, and the criteria used to assess that failure.

Analyzing IT Project Failure

IT project failure has many reported causes, including lack of alignment between project and business objectives, poor project management practices, lack of senior management support, lack of user involvement, poor requirements management, inaccurate estimation, and project team inexperience (Standish Group, 1994, 1999, 2001a, 2001b, 2007, 2008, 2009). Literature on IT project failure, however, has tended to be focused more on contributing factors than on the criteria used to determine failure.

From a strategic perspective, Hartman and Ashrafi (2002) cited a lack of alignment between business and project objectives among the mostly managerial and organizational causes they identified for IT project failure. From their review of the literature, they determined seven most frequently reported causes:

1. Misunderstood requirements
2. Optimistic schedules and budgets
3. Inadequate risk assessment and management
4. Inconsistent standards and lack of training in project management
5. Management of resources (people more than hardware and technology)
6. Unclear charter for project
7. Lack of communication

Their methodology also included investigation of the existence of critical success factors (CSFs) to avoid project failure, and the extent to which project metrics were developed to measure project performance against each CSF. Survey data was collected from 36 participants on 12 Canadian IT projects. Results indicated problems with alignment between project metrics and CSFs, as well as a lack of consensus on metrics and CSFs among project stakeholders.

Ewusi-Mensah (1997) and Ewusi-Mensah and Przasnyski (1995) suggested organizations undertake regular investigations of abandoned information systems projects in order to identify causes of failure within their organizations and develop lessons learned for improving future project performance. Glass (1998) and Johnson (2006) both investigated the causes of IT project failure qualitatively. Johnson (2006) leveraged his research experience with the Standish Group to gather and categorize potential causes of IT project failure, organizing them into sets of lessons elaborating on consistent themes. Glass' case study analysis of conditions leading to a software project runaway or "a project that goes out of control primarily because of the difficulty of building the software needed by the system" (p. 3), revealed the following causes of runaway projects, in descending order of frequency:

1. Project objectives not fully specified
2. Bad planning and estimating
3. Technology new to the organization
4. Inadequate/no project management methodology
5. Insufficient senior staff on the team
6. Poor performance by suppliers of hardware/software
7. Other -- performance (efficiency) problems

Glass loosely defined an out-of-control project as one which is impossible to manage in order to "meet its original target goals, or to even come close to them" (p. 3), contrasting this definition with the more specific and restrictive version used by consulting firm

KPMG (Cole, 1995) which considered a runaway project to be one that failed to achieve its objectives or exceeded its original budget by 30% or more. Most research into IT project failure has applied similar criteria based primarily on project schedule, scope, and cost (Standish Group, 1994, 1999, 2001a, 2001b, 2007, 2008, 2009), however, the use of such quantitative, rational project success criteria on projects that are often non-linear and complex may have unintentionally contributed to the low success rate on complex IT projects and made IT project failure appear more common.

Using a more quantitative approach to determining the causes of IT project failure, Kappelman, et al. (2006) compiled early warning signs of IT project failure through literature review, then asked 19 project management experts to evaluate and refine the list. The resulting set of 53 indicators was then rated for importance by surveying 55 experienced IT project managers. Similar indicators with high scores for importance were combined and grouped into one set of people-related risks and another set of process-related risks. High-scoring people-related risks included management support, project manager skills, stakeholder involvement, team commitment and skills, and subject matter expert availability. Process-related risks included requirements management and success criteria, change control, schedule planning and management, stakeholder communication, resource availability, and strength of a business case.

El Emam and Koru (2008) performed a replicated quantitative study of IT project cancellation in 2005 and 2007. Focusing specifically on software development projects conducted by Cutter Consortium clients, they found a 15.52% cancellation rate in 2005 and an 11.54% cancellation rate in 2007, a difference that was not significant, $p = .19$, with their sample sizes of $N = 232$ and 156, respectively. However, for projects that did fail, $n = 18$ in the 2007 study, the most commonly cited reasons for cancellation included senior management neglect and requirements change, both 33%, 95% *CI* [13, 59]; and lack of skills and being over budget, both 28%, 95% *CI* [10, 54].

Defining IT Project Success

Many traditional measures of project success like the triple constraint which considers project schedule, scope, and cost, were adopted when formal project management theory emerged from the field of operations research (Morris, 1994). Subsequent developments in project management theory and practice have led to the establishment of a wider range of project success criteria, including those that consider both the process and the product of the project (Baccarini, 1999), as well as those which measure the project's contribution to the organization, its stakeholders, and its environment (D. Brown, Dillard, & Marshall, 2006). Researchers have also investigated the application of contingency-based models where project success criteria vary by project categories and types (Evaristo & van Fenema, 1999) and found that the subjective perception of project success often differs from its quantitative measurement (Besner & Hobbs, 2006; White & Fortune, 2002).

The triple constraint. The triple constraint, so named because of its original focus on project schedule, scope, and cost, is a combination of the three most fundamental project success metrics (Kerzner, 2006; Project Management Institute, 2008a). The relationship between these three metrics is usually represented as a triangle, emphasizing that they are interdependent. Accumulated knowledge and best practice usually assert that no more than two of the three components of the triple constraint can be fixed, or held inflexible, or a project is overconstrained (Kerzner, 2006; Lewis, 2005).

Contemporary versions of the triple constraint often incorporate additional dimensions such as product quality and customer satisfaction (Frame, 1994). These enhancements emerged to compensate for the tendency of project teams to take shortcuts in response to overconstrained projects with fixed schedules, scope, and budget, and in reaction to increasing emphasis on the ultimate quality and customer satisfaction delivered by the project (Lewis, 2005). Even with these additional components, the triple constraint is primarily a short-term, project-focused measure of success.

The triple constraint has been applied to IT projects with varying degrees of effectiveness. Agarwal and Rathod (2006) surveyed programmers, project managers, and customer account managers within Indian contract software development organizations that had received high Capability Maturity Model (CMM) ratings, chosen specifically because of the expected maturity level of software development processes. While they found differences between the means and relative rankings of project scope, cost, schedule, and a fourth criteria for project quality among the three groups of participants, the organizations still applied the modified triple constraint as their primary set of criteria for project success. Atkinson (1999), however, questioned the reliability of project success criteria based on the triple constraint, pointing out the difficulty of estimating and measuring project cost and duration, and citing the subjective, lagging-indicator nature of project quality. In spite of these limitations, the widely-cited Standish Group (Standish Group, 1994, 2009) research has used a definition of project success based on the triple constraint which classifies projects into those which are:

1. Completed on time and on budget, with all features and functions as initially specified (successful)

2. Completed and operational but over budget, late, with fewer features and functions than originally specified (challenged)
3. Canceled before completion or never implemented (failed)

While the reliability and validity of the Standish studies has been questioned (El Emam & Koru, 2008; Glass, 2006b) and the actual survey questions remain proprietary, the Standish project success metrics have been widely quoted for more than 10 years.

Process and product success. Differentiating between the success of the project management process and the ultimate product of the project, Baccarini (1999) applied a logical framework method to project success that distinguished between project inputs and outputs as components of project management success, and project goals and purposes as components of the project's product success. In defining the two types of project success, Baccarini listed three components of project management success including meeting:

1. Project time cost and quality objectives
2. Quality objective for the project management process
3. Stakeholder needs related to the project management process

He also defined the three standards of product success as meeting:

1. Strategic organizational objectives
2. User needs
3. Stakeholder needs related to the product

Recognizing project success as multidimensional and citing several examples, Baccarini pointed out it is possible to succeed on one set of project success criteria and fail on another. He also adopted the position that product success is more important than project management success, explaining why some projects that are perceived as project management failures are ultimately recognized for delivering successful products. This expanded view of the contribution of the project has been further elaborated by other researchers.

Project contribution. Shenhar and Wideman (1996a) adopted a project contribution perspective in a PMI symposium paper on the dimensions and criteria of project success. One of their four dimensions considered internal project objectives, while the other three evaluated immediate benefit to the customer and medium and long-term benefits to project stakeholders as a whole:

1. Internal project objectives (efficiency during the project)
2. Benefit to customer (effectiveness in the short term)
3. Direct contribution (in the medium term)
4. Future opportunity (in the long term)

Attempting to correlate success criteria heuristically with project type, industry sector, system size, and technology content, they conceded there was still no consistent framework for defining IT project success.

In a study measuring characteristics of successful IT projects in Norway, Karlsen, Andersen, Birkely, and Odegard (2005) identified similar contribution-related criteria for IT project success. Survey data provided by 140 members of the Norwegian Center of Project Management was used to investigate the importance of 16 project success criteria on a Likert-type scale ranging from 1 = not important to 5 = very important. The five highest rated responses all considered project contribution (p. 533):

1. The IT system works as expected and solves the problems ($M = 4.62$)

2. Satisfied users ($M = 4.49$)
3. The IT system has high reliability ($M = 4.43$)
4. The solution contributes to improved efficiency and competitive power ($M = 4.31$)
5. The IT system contributes to the realization of goals ($M = 4.30$)

Project characteristics such as meeting technical requirements, delivering on schedule and under budget, and minimizing implementation problems all ranked lower.

Procaccino and Verner (2006) also explored dimensions of project contribution with a quantitative study measuring project outcomes among 74 U.S. organizations performing software development. Delivering a system that met requirements ranked as the most important project success criteria for both project managers and practitioners, with 95% and 93% respectively rating it a 6 or 7 on a 7-point Likert-type scale. Performing work that was intrinsically rewarding was the second-highest ranked outcome, with 95% and 97% respectively rating it a 6 or 7.

The focus on project contribution considers the importance of the project in the context of organizational goals and objectives. Further differentiating between project success criteria strictly measuring internal project performance and criteria intended to align project success with organizational effectiveness; other researchers have investigated the application of different sets of project success criteria to different types or categories of projects.

Project categories. Several researchers have developed models or typologies categorizing projects according to their characteristics (Archibald & Voropaev, 2004; Avison & Taylor, 1997; Evaristo & van Fenema, 1999). Some studies incorporating project typologies have also applied different definitions of success to different categories of projects. A contingency approach (Lawrence & Lorsch, 1967) was used by Shenhar and Wideman (1997) to discuss the applicability and importance of various project success categories and project management methods for projects with differing degrees of technology content. Suggestions included that projects using established technology were most likely to meet, and were most appropriately measured by, internal project objectives, while projects using highly advanced technology were most likely to overrun internal project success criteria, yet also most likely to deliver large benefits to customers and significant medium term and long term advantages to the organizations that undertake them.

IT effectiveness. Since the ultimate objective of most IT projects is to deliver or enhance information systems, IT project success can also be measured in terms of IT effectiveness. Ness (2005) incorporated the research of Tallon, Kraemer, and Gurbaxani (1999) identifying three characteristics of IT effectiveness with high construct validity including (a) user satisfaction, (b) quality of service, and (c) helpfulness of the IT staff as part of a study investigating the relationships among strategic alignment, IT flexibility, and IT effectiveness. Kanungo, Duda, and Srinivas (1999) constructed an integrated model of IS/IT effectiveness factors categorized by their degree of dependence on other factors. Testing of their model through surveys of 40 Indian organizations across varying industries and stages of growth and 120 interviews of managers at various organizational levels indicated the most important factors in IT effectiveness were (a) improving systems integration, (b) facilitating information retrieval, (c) increased user satisfaction,

(d) improving quality of product/service, and (e) minimizing errors/mistakes and functional areas.

Further integrating the concept of IS effectiveness with the broader perspective of the balanced scorecard (Kaplan & Norton, 1996), Barclay (2008) developed a project performance scorecard with six major dimensions or perspectives:

1. Project process
2. Stakeholders
3. Learning and innovation
4. Project benefits
5. Process and product quality
6. Users

The approach was tested with a case study of a Caribbean financial services firm's implementation of an online employee recruitment system. The project was considered unsuccessful when evaluated with traditional triple constraint measures. Questionnaires and interviews were used to investigate reasons for the initial perception of failure, and to evaluate the project against the broader definition of project success. Results supported the researcher's premise that success criteria within each perspective were project-specific and best determined in collaboration with key stakeholders.

Other approaches. Other alternatives to defining project success include approaches based on life cycle stages (Khang & Moe, 2008), alignment with project owner goals (Jugdev & Muller, 2005), and organizational sustainability (D. Brown, et al., 2006). Furthering the contingency-based, project categorization approach, Khang and Moe (2008) suggested different project success criteria were applicable to different stages of the project life cycle. However, their list of suggested success criteria for the phases of conceptualizing, planning, implementing, and closing/completing was essentially a checklist of effective project management practices. Since they focused on such practices as identifying and addressing the needs of specific target groups, carrying out activities as scheduled, and delivering a project completion report, their life cycle stage success criteria were focused primarily on project management processes. They did, however, suggest additional measures of overall project success which focused more on the benefits of the project to the organization and its stakeholders. Jugdev and Muller (2005) extended the contingency model to perhaps its ultimate conclusion by suggesting that project success criteria should be whatever is agreed upon by the project owner and project manager, since the project owner is typically responsible for both the project opportunity or problem, and the resources used to address it.

Shenhar, Dvir, Levy, and Maltz (2001) evaluated project success criteria in the context of organizational effectiveness and strategy. The two-stage, mixed-methods study first evaluated 15 project case studies of varying degrees of technical complexity for common attributes of successful projects, then collected and analyzed survey data on 127 projects across 76 organizations and five broad industry groups. Generalizability was limited due to non-random selection of the case studies and projects; however, correlation coefficients and factor analysis of survey data indicated project success factors are multi-dimensional and vary according to project complexity and time frame. Wateridge (1998) followed survey data collection from 132 respondents with qualitative interviews describing 12 IT projects. While the relative ranking of success criteria differed between users and project managers, results also indicated IT project success criteria are more numerous than scope, time, and budget, and must be defined explicitly for each project.

The triple bottom line (D. Brown, et al., 2006) is an emerging concept for assessing organizational economic, social, and environmental performance. With origins in sustainability, it measures an organization's contributions to profit, people, and planet. Seeking a realistic combination of all three types of objectives, the triple bottom line recognizes that economic sustainability is a necessary precondition for social and environmental sustainability. The wide range of IT project success criteria indicates the existence of a number of factors affecting IT project success, the subject of the next section.

Factors Affecting IT Project Success

Project success is multidimensional (Shenhar, et al., 2001). It is also influenced by a number of factors, including the use of project management maturity models, the practice of software process improvement, and the analysis and application of critical success factors. Distinguishing between project success criteria and factors influencing it, Lim and Mohamed (1999) surveyed the literature of project critical success factors and determined that while numerous factors affect internal project success, external project success could be sufficiently determined through the two "macro" criteria of project completion and user satisfaction.

As part of a larger study of project management practice, White and Fortune (2002) used survey data gathered from 236 respondents across multiple industries and project types to compare the perception of project success with performance against elements of the triple constraint, and determined that perceived project success is often better than measured performance indicates. Similarly, Ojiako, et al. (2008) addressed the subjective nature of perceived project success with a grounded theory approach using interview data from 15 project managers in three UK construction firms and five UK IT firms to identify factors most likely to influence product success in practice. Textual analysis identified 24 potential factors from 163 transactional events; most common themes included information availability, technology use, design effectiveness, requirements management, project complexity, and success criteria. In the following sections, other practices and factors potentially having a significant impact on the perception and measurement of IT project success are also reviewed.

Project management maturity. Advocates of project management maturity models claim they increase project success (J. K. Crawford, 2006; Jugdev & Thomas, 2002; Pennypacker & Grant, 2003; Persse, 2007; Project Management Institute, 2004; Sidenko, 2006), but they typically do not qualify the types of organizations and projects for which greater project management maturity is beneficial. Maturity models are generally structured in a manner similar to the Software Engineering Institute's Capability Maturity Model (Curtis, Hefley, & Miller, 2001, 2002; Paulk, 1999; Paulk, Curtis, Chrisis, & Weber, 1993; Paulk, Weber, Garcia, Chrisis, & Bush, 1993). Software process improvement (SPI) is, in essence, a structured approach to improving software process maturity, therefore its influence on IT project success is secondary, however some SPI research suggests that more effective execution of certain software development practices leads to greater IT project success (Baddoo, Hall, & Wilson, 2000; Conradi, 1997; Grady, 1997; Austen Rainer & Hall, 2002; Wiegers, 1999). Common examples of project management maturity models include the Project Management

Institute's (2004) Organizational Project Management Maturity Model (OPM3) and Kerzner's (2006) project management maturity model (PMMM). Project management maturity models are gaining in recognition, but in an assessment of actual maturity levels Pennypacker and Grant (2003) found that nearly 70% of benchmarked organizations were at Level 2 or below of the representative five-level project management maturity developed by Crawford (2006).

Sidenko (2006) further studied the relationship between project management maturity and project success. She first defined project success using four components derived from a review of the literature:

1. Project efficiency
2. Impact to the customer
3. Business success
4. Preparation for the future

After collecting survey data from 109 members of the Montreal PMI chapter, she applied a structural equation modeling process to determine the statistically significant relationships between components and project success. Results indicated the two significant factors of project success were:

1. Project efficiency ($r^2 = .90$, $p = .01$)
2. Business success ($r^2 = .89$, $p = .01$)

To develop the initial model, Sidenko evaluated J. K. Crawford's (2006) Project Management Solutions project management maturity model (PMMM). A positive correlation was found to exist with project success, indicating a positive relationship between project management maturity and project success. However, the study did not apply moderating variables such as project type, project size, or project complexity.

Critical success factors. Extensive research has been performed on IT project critical success factors (CSFs). A commonly cited list of IT critical success factors is the Chaos Ten derived from the Standish Group's (1994, 1999, 2001a, 2001b, 2007, 2008, 2009) research of IT project success and failure. Factors determined by Standish (2001) to reduce the incidence of IT project failure include:

1. Executive support
2. User involvement
3. Experienced project manager
4. Clear business objectives
5. Minimized scope
6. Standard software infrastructure
7. Firm basic requirements
8. Formal methodology
9. Reliable estimates
10. Other: small milestones, proper planning, competent staff and ownership

Similarly, Belassi and Tukel's (1996) integrated framework, derived from their analysis and synthesis of seven comprehensive studies, grouped project CSFs into factors related to the project, the project manager and team, the organization, and the external environment. Westerveld (2003) developed a model relating project critical success factors to project success across five project types after defining the six results areas for measuring project success. Christenson and Walker (2004) examined the role of vision as a critical success factor in project success with four case studies of large IT projects. Examples from literature were leveraged to develop a suggested process for developing a project vision to improve the likelihood of success. Sigurðarson (2009) cited Westerveld's model in developing a qualitative survey of Icelandic members of the International Project Management Association (IPMA) to investigate ethical standards as project critical success factors. The study measured agreement with descriptive statements and indicated projects where ethical risks were considered and addressed (32%) were more likely to have been managed by experienced project managers.

Boynton and Zmud (1984) applied CSFs to MIS planning and found CSFs were more effective in planning than was requirements analysis. White and Fortune (2002) used a survey to collect data from 236 project managers in both public and private sector organizations and found the three factors most frequently identified as critical to project success were (a) clear goals/objectives, (b) support from senior management, and (c) adequate funds/resources. Hartman and Ashrafi (2002) developed metrics for measuring the extent to which critical success factors on projects are carried out. Surveys were completed with 36 participants on 12 Canadian IT projects and used to evaluate CSFs and project metrics by project phases and stakeholder groups. The importance of CSFs did not vary significantly across project phases or among stakeholder groups, however, there was less agreement on how success factors should be measured. Dvir, et al. (2006) studied the relationship between project manager personality, project categories, and project success. Results indicated few significant correlations between self-reported project manager personality characteristics and project success, however investigative traits were negatively correlated with customer satisfaction on derivative projects, r^2 = -

.34, $p < .05$, entrepreneurial traits were positively correlated with new opportunities on platform projects, $r^2 = .47$, $p < .05$, and interestingly, type A behavior was negatively correlated with efficiency on high-tech projects, $r^2 = -.65$, $p < .05$.

Project success criteria and IT project success. Project success is the degree to which a project meets its success criteria. These criteria can be implicitly perceived or explicitly defined and measured. Saleh and Alshawi (2005) applied a constructionist view to classify IT project success measurement approaches into those focused on the product, the process, and project management maturity. Finding these categories insufficient, they developed an approach incorporating the four dimensions of information technology, process, people, and the organizational environment. In their approach, success was determined by first measuring the difference between the current situation and the desired situation for each of these four factors, the measuring it again after the project was completed.

Wateridge (1998) also suggested most existing schemes for measuring IT project success were focused on too narrow a range of success criteria. From existing literature and research he distilled a short list of five success criteria applicable in various combinations of priority and emphasis to most projects:

1. Meets user requirements
2. Happy users
3. Achieves purpose
4. Meets budget
5. Meets time

Keil, Mann, and Rai (2000) evaluated IT project success from the perspective of project escalation. Using survey data from 579 US information systems auditors, they applied theoretical frameworks including self-justification, prospect theory, avoidance theory, and approach-avoidance theory to identify potential causes of IT project escalation. Correlation analysis indicted sunk cost, information asymmetry, project size, and goal incongruency were the strongest predictors of IT project escalation. Three different escalation measures indicated 30% to 40% of IT projects were escalated. Using categorical measures of implementation, budget, and schedule performance, 23% and 84% of escalated and non-escalated projects respectively were found to be successful.

In a mixed-methods study of the success of software process improvement (SPI) projects, Rainer and Hall (2003) conducted group interviews with developers, project managers, and senior managers from 13 international telecommunications, aviation, and technology organizations, and collected survey data from a larger sample of 84 such organizations. A total of 26 potential success factors were identified from interview transcripts and analyzed for frequency of occurrence. The set was reduced to 18 core factors investigated in the survey stage of the study. Executive support, staff experience, and process maturity were all found to be strongly related to software process success. Further analysis of their findings led them to reduce the factors to a potentially oversimplified but revealing list wherein the three most significant factors were people, problems, and change.

In another mixed-methods study, Dvir, Raz, and Shenhar (2003) investigated the relationship between project planning and project success. Requirements, specifications, and project management processes were used to measure project planning. Project success was evaluated against five measures from the perspective of end users, project managers, and contracting officers. Survey and interview data from 110 Israeli defense R&D projects were analyzed with descriptive and correlational statistical methods. Using a significance level of $p = .001$ to reduce the risk of Type I error, there was a high correlation, $r^2 = .572$, $p = .000$, between functional specifications and technical specifications, but no correlation between planning and quality of functional specifications, $r^2 = .128$, $p = .205$, or technical specifications, $r^2 = .127$, $p = .241$. Interestingly, there was no significant correlation between the planning process and any measure of success, however, achieving internal project planning goals was highly correlated to delivering end user benefits, $r^2 = .621$, $p = .000$; contractor benefits, $r^2 = .317$, $p = .001$; and overall project success, $r^2 = .570$, $p = .000$. Interpretations included the possibility that specific planning processes are less important to project success than is simply setting and meeting project success goals.

From this overview, it is apparent that IT project success depends as much, if not more, on the implicit or explicit selection of project success criteria as it does on critical success factors, project management processes, and project execution. In the following section, the role of IT project complexity is reviewed.

IT project complexity and IT project success. Several researchers have suggested a relationship between IT project complexity and IT project success. Hass (2009) cited the coinciding trends of increasing project complexity and decreasing project success as evidence of such a relationship. Austin, et al. (2002) assumed project complexity decreased project success and therefore managing project complexity would increase success. Jaafari (2003) described the characteristics of complex systems as evidence that complexity makes project success more difficult.

Xia and Lee (2004) tested four project complexity constructs and their relationships to project success with survey data collected from 541 North American IS project managers belonging to the PMI IS-SIG. They found regression coefficients ranging from $r = -.311$ to $-.395$, $p < .01$ between structural organizational complexity and project cost, functionality, delivery time, and user satisfaction, respectively. Dynamic organizational complexity had a regression coefficient of $r = -.085$, $p < .1$ with project cost, and dynamic IT complexity had a regression coefficient of $r = -.091$, $p < .05$ with functionality; however, they found no correlation between structural IT complexity and any of the four dimensions of project success.

Burkatzky (2007) elaborated on the four complexity constructs developed by Xia and Lee (2004) by including additional factors pertaining to project manager and team member workload, project leadership, geographic dispersion, and language barriers. Using a measure of project success derived from four dimensions of system integration performance, results indicated a positive correlation between project complexity and system integration performance, $r = .339$, $p = .01$.

Organizational paradigms and project success criteria. Applying the organizational paradigms to the literature of project success criteria illustrates that the criteria most commonly used to define project success are predominantly based on the rational systems view (see Table 3). Project success criteria also appear to vary from primarily quantitative to primarily qualitative, from internal to external, and from short term to long term as organizational paradigm varies from the rational systems view, to the natural and open systems views, to the complex adaptive systems view.

Table 3

Organizational Paradigms and Sample Project Success Criteria

Rational	Natural/Open	Complex adaptive
Cost, time, scope - triple constraint	Quality	New product/LOB
Process success	Customer satisfaction	New technology
Project profit, ROI	Market share	Profit, people, planet - triple bottom line
	Product success	Sustainability
	Organization profit, ROI	

Recent research in this area reveals a trend toward more subjective and qualitative measures of project success, particularly for IT projects with a high degree of complexity (Baccarini, 1999; Besner & Hobbs, 2006; D. Brown, et al., 2006; Evaristo & van Fenema, 1999).

Literature Review Summary

Although its history as an academic field is relatively short, project management theory has been modeled, analyzed, and categorized using a number of approaches including historical trends (Anbari, et al., 2008; Bredillet, 2007a, 2007b, 2007c, 2008a, 2008b, 2008c), project categories and typologies (Archibald & Voropaev, 2004; Avison & Taylor, 1997; Evaristo & van Fenema, 1999; Shenhar & Dvir, 1996; Shenhar & Wideman, 2002), management domains (D. K. Anderson & Merna, 2003), contingency domains (Shenhar, 2001), analytical decomposition (Koskela & Howell, 2002), the resource-based view (Jugdev, 2004), and actuality-based grounded theory (Cicmil, et al., 2006). However, the need still exists for a theoretical framework of project management (Williams, 1999). Viewing projects as temporary organizations (J. R. Turner & Muller, 2003) allows the application of organizational paradigms from general systems theory (Katz & Kahn, 1966; Parsons, 1960; Scott, 2003; J. D. Thompson, 2003). Extending the organizational paradigms to include complex adaptive systems (Buckley, 1968; Gleick, 1988; Hass, 2009; Holland, 1992; R. Lewin, 1992; J. H. Miller & Page, 2007; Mueller, 2004; Pines, 1998; Stoltz, 2004) enables this approach to accommodate project complexity.

Researchers (Austin, et al., 2002; Baccarini, 1996; Bardyn & Fitzgerald, 1996; Brockhoff, 2006; Cooke-Davies, et al., 2007; Fitzgerald & Bardyn, 2006; Frame, 1994; Jaafari, 2003; Singh & Singh, 2002; Whitty & Maylor, 2007) have agreed that project complexity tends to occur when:

1. The problem or opportunity is not clearly defined.
2. There are a large number of unknowns.
3. The requirements are unclear and volatile.
4. The outcome is unpredictable.
5. The project schedule is over-ambitious or over-constrained.
6. The project uses or creates new technology.
7. There is a rapid rate of technological change.
8. There are significant political and social influences.
9. There are critical external dependencies and constraints.
10. The project itself creates significant change.

The causes of project complexity can be further distinguished from characteristics which tend to make projects more complicated (Cilliers, 1998; Hass, 2009), for example:

1. The project cost is high.
2. The project duration is long.
3. The project team is large and/or geographically dispersed.
4. The project team lacks experience with the project content or technology.

Information technology projects are among the most complex types of projects encountered, since software development in particular is one of the most difficult activities undertaken by humans (Brooks, 1975; McConnell, 1996). Information technology project complexity has been modeled using a number of different approaches. The Hass (2007a, 2007b, 2009) project complexity model, the NTCP model (Sauser, Reilly, & Shenhar, In Press; Shenhar & Dvir, 2007b), and other models of project complexity (Kim & Wilemon, 2009; Xia & Lee, 2004, 2005) offer differing perspectives and degrees of detail on the underlying dimensions and factors contributing to project complexity.

Information technology project success has also been studied from a number of different perspectives. Early approaches derived from the triple constraint have been supplanted by a wider range of project success criteria, including those that consider both the process and the product of the project (Baccarini, 1999), as well as those which measure the project's contribution to the organization, its stakeholders, and its environment (D. Brown, et al., 2006). Researchers have also developed contingency-based models where project success criteria vary by project categories and types (Evaristo & van Fenema, 1999).

Project success can be defined as the degree to which a project meets its project success criteria, whether the criteria are implicitly perceived or explicitly defined and measured (Besner & Hobbs, 2006; White & Fortune, 2002). Several researchers have suggested a relationship between IT project complexity and IT project success (Austin, et al., 2002; Hass, 2009; Jaafari, 2003) but to date few models relating the two have been tested empirically (Burkatzky, 2007).

CHAPTER 3. METHODOLOGY

The purpose of this study was to investigate the relationship between IT project complexity, complication, and success. The problem addressed was the low success rate of IT projects in the U.S. and worldwide. The role of IT in advancing strategic and tactical objectives gives it critical importance to organizational leaders (Tallon, et al., 2000), yet approximately two-thirds of IT projects are considered unsuccessful (Standish Group, 2009). In this chapter, the research design is defined and described.

Research Design

A pragmatic perspective suggests the selection of a research design should be influenced by the nature of the problem being investigated (Arbnor & Bjerke, 1997; Onwuegbuzie & Leech, 2005). This study was intended to investigate the relationships between project complexity, project complication, and project success. Other researchers (Rakhman & Zhang, 2008) have identified similar attributes of project complexity in qualitative case studies, but have conceded that further studies with larger sample sizes are required to confirm relationships between project characteristics. In this study, a distinction was made between IT project complexity (ITPCx) and IT project complication (ITPCn) in order to examine the possibility that these two sets of project attributes affect the likelihood of IT project success (ITPS) differently. When the intent of a study is to predict, test, confirm, or explain observed phenomena, quantitative methods are the preferred approach (Cooper & Schindler, 2003). A quantitative experimental design was precluded by the difficulty of manipulating variables representing project characteristics and the time frame required to measure project outcomes, thus making it impractical to attempt to confirm causality. Instead, a quantitative correlational analysis of survey data representing multiple projects permitted assessing relationships among variables and constructs representing project characteristics to assess whether such characteristics were correlated. Evidence of correlation does not indicate causality, but can identify relationships which practitioners may find applicable and researchers can explore further.

A quantitative, correlational design is characteristic of the logical positivist research tradition. Underlying the positivist tradition and all research paradigms are certain ontological, epistemological, and axiological assumptions. These assumptions influence the researcher's perception of the problem to be studied (Creswell & Plano Clark, 2007). With its origins in the analytical philosophical worldview of 5th century B.C. Greece (Jones, 1970), positivism reflects the ancient Greek ontological view of reality as objective, rational, concrete, and divisible, and therefore best understood by deconstructing, analyzing, and explaining its separate parts (Arbnor & Bjerke, 1997). Identifying project characteristics that are potentially related to project complexity and project complication and treating projects as rational systems that are divisible, separable, and measureable is consistent with a positivist analytical approach.

In addition to this concrete analytical view of reality, the positivist paradigm also incorporates an epistemological perspective that views the researcher as separate and independent from the phenomena being observed. Survey research is particularly effective for measuring such phenomena when an experimental approach is not feasible (Arbnor & Bjerke, 1997). The assumption of independence from the phenomena being observed is also consistent with the positivist axiological position that the researcher is unbiased and seeks to avoid imposing personal values on observations. The validity and reliability testing inherent in quantitative descriptive correlational research design reinforces the positivist axiological viewpoint and increases reproducibility and generalizability (Cooper & Schindler, 2003).

While a positivist approach was adopted in this study, many researchers maintain that IT projects do not always behave according to a deterministic, positivist paradigm (Brooks, 1995; Hass, 2009; Whitty & Maylor, 2009). Complex adaptive systems such as IT projects tend to be highly sensitive to small variations in initial conditions (Garmon, 2004), change in response to attempted interventions (Churchman, 1967; Rittel & Webber, 1973), and display outcomes that are unpredictable (Lorenz, 1972). Complexity science has been proposed as an alternative approach to organizational analysis (McKelvey, 1999; K. A. Richardson, et al., 2000) that complements and extends systems theory to accommodate complex adaptive systems (Phelan, 1999, 2001).

Complexity science, therefore, is more consistent with an interpretivist paradigm than with logical positivism (R. Weber, 2004). An interpretivist ontological perspective incorporates a view of the nature of reality as inseparable from and influenced by the researcher rather than separate and distinct. Interpretivist epistemology also views knowledge as intentionally constructed from the researcher's history and lived experience, rather than objectively observed and measured. Interpretivist axiology explicitly recognizes and openly discusses the influence of the researcher's values and experience (Creswell & Plano Clark, 2007).

The two perspectives are not incompatible, however. Morcol (2001) viewed complexity science as postpositivist and complementary to logical positivism. Such a dialectical perspective accepts differences between research paradigms and encourages applying different paradigms to different problems (Gioia & Pitre, 1990). Furthermore, different paradigms may apply simultaneously to different analytical units of study (Arbnor & Bjerke, 1997). While a single project may behave as a complex adaptive system consistent with an interpretivist paradigm, a population of projects may exhibit aggregate behavior more consistent with a logical positivist paradigm. This paradigmatic paradox is consistent with chaos theory which suggests the behavior of individual organisms and systems may appear random and unpredictable, but is actually governed by determinable principles (Lorenz, 1963).

After the quantitative correlational design was selected, the literature was reviewed to identify constructs, elements, and previously existing instrumentation. It was determined that no existing models of project complexity distinguished between project characteristics which tend to increase project complexity, and those which tend to increase project complication. Several models of project complexity were analyzed in order to synthesize constructs for IT project complexity (ITPCx) and IT project complication (ITPCn).

Some existing models assessed dimensions of project complexity using ordinal categories. Hass (2009) defined three categories of complexity for each dimension, while Shenhar and Dvir (2007b) used three categories for some dimensions and four categories for others. Others models assessed project complexity with interval scales. Xia and Lee (2004, 2005) measured four types of information systems development project (ISDP) complexity using seven-point Likert scales. While some researchers have suggested that three-point Likert-type scales are adequate (Jacoby & Matell, 1971), others have found that a greater number of steps tends to increase validity and reliability (Cox III, 1980). In this study all measurements of construct elements for IT project complexity and IT project complication were standardized to five-point ordinal Likert-type scales. Since the scales had not been previously validated, the data collection strategy included an intermediate step for survey instrument validation.

Assessing whether traditional definitions of project success were appropriate for complex IT projects was outside of the scope of the current study; therefore for the purposes of the study, project success was also measured using the three categories developed and defined by the Standish Group (1994, 2009): successful, troubled, and failed. However, in order to compensate for the tendency observed in the literature for complex projects to experience greater change in scope, budget, and schedule than do less complex projects (Hass, 2009; Shenhar & Dvir, 2007b), project success was measured against both initial project goals and objectives (baseline 1), as well as against final project goals and objectives (baseline n).

Research Questions and Hypotheses

The study addressed the following research questions and hypotheses:

RQ1: To what extent, if any, is IT project complexity related to IT project complication?

$H1_0$: IT project complexity is not correlated with IT project complication

$H1_A$: IT project complexity is correlated with IT project complication

RQ2: To what extent, if any, is IT project complexity related to IT project success?

$H2_0$: IT project complexity is not correlated with IT project success

$H2_A$: IT project complexity is correlated with IT project success

RQ3: To what extent, if any, is IT project complication related to IT project success?

$H3_0$: IT project complication is not correlated with IT project success

$H3_A$: IT project complication is correlated with IT project success

RQ4: To what extent, if any, is IT project complexity more strongly related to IT project success than is IT project complication?

$H4_0$: IT project complication has an equal or greater correlation with IT project success than does IT project complexity

$H4_A$: IT project complexity has a greater correlation with IT project success than does IT project complication

While there was extensive anecdotal evidence that project complexity and project complication negatively affect project success (Hass, 2009), no prior studies were identified which had empirically tested these relationships.

Conceptual Model

In this study, the relationships between IT project complexity (ITPCx) and IT project complication (ITPCn) and their individual relationships to IT project success (ITPS) were investigated (see Figure 5). Defining IT project complexity as the degree to which an IT project exhibited the characteristics of a complex adaptive system allowed further distinguishing between factors contributing to project complexity and factors increasing project complication. Similarly, IT project success was defined as the degree to which a project met its success criteria.

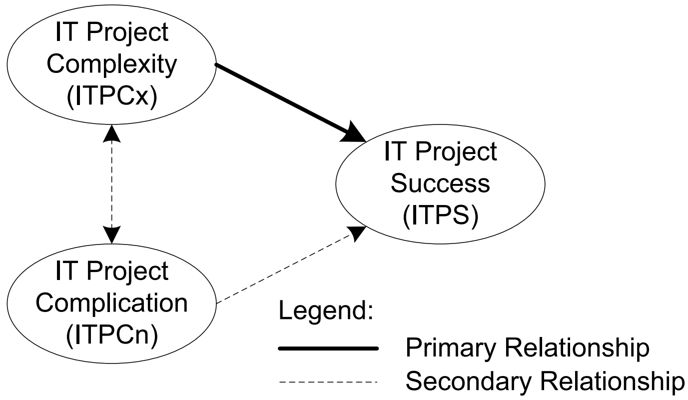


Figure 5. Conceptual model of IT project complexity, IT project complication, and IT project success.

While existing models of project complexity did not distinguish between IT project complexity and IT project complication, the two concepts could be differentiated by their potential effects on project behavior and outcomes (Arthur, et al., 1997; Cilliers, 1998; Durlauf, 1997). From the literature review, a model of IT project complexity and complication (PCC) was synthesized which further subdivided project characteristics among these two constructs. Project characteristics likely to contribute to project complexity included the following (Hass, 2009):

1. Schedule reasonableness and flexibility
2. Degree of internal or external project staffing
3. Extent of team shared history and prior success
4. Degree to which formal or informal methodologies are used
5. Clarity and stability of organizational objectives
6. Clarity and familiarity of the project opportunity or problem
7. Degree to which the solution is known and defined
8. Degree to which requirements are known and stable

9. Extent of organizational and technological change

10. Nature of the political and regulatory environment

11. Degree of IT complexity

12. Degree of integration required with other systems

Figure 6 depicts these elements of ITPCx graphically.

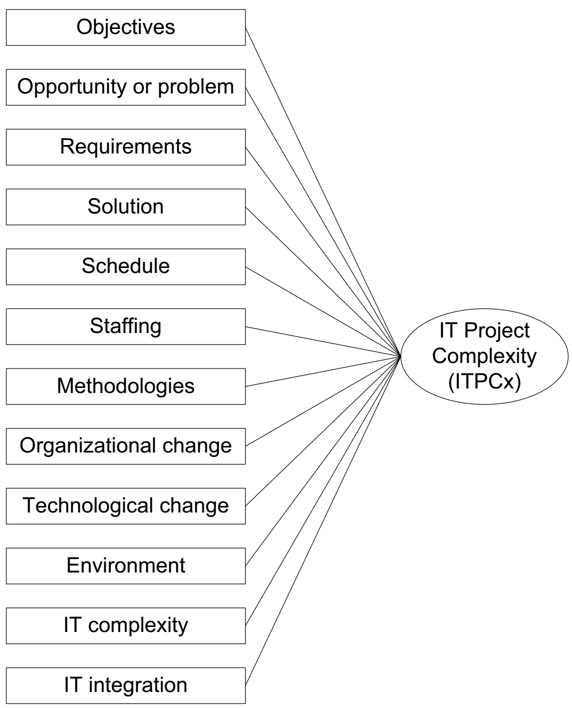


Figure 6. Elements of IT project complexity.

Similarly, factors contributing to project complication were considered (Hass, 2009):

1. Project duration

2. Project cost

3. Project team size

4. Project leadership experience

5. Scope achievability and flexibility

6. Organizational support and involvement

7. Extent and familiarity of contract relationships

8. Technology content

Figure 7 depicts the elements of ITPCn graphically.

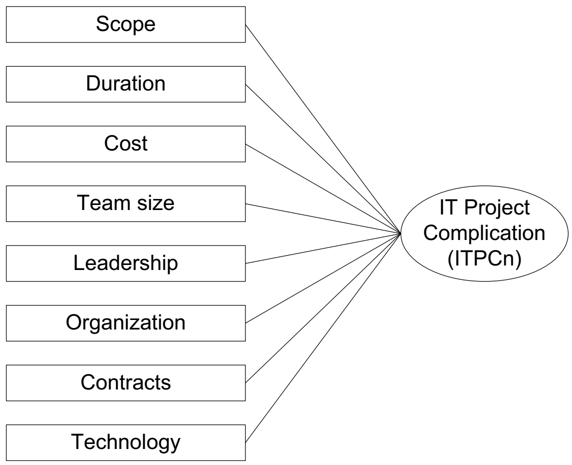


Figure 7. Elements of IT project complication.

Project success and IT project success have been defined in numerous ways (Baccarini, 1999; Glass, 2006b; Standish Group, 2009). In order to maximize the opportunity for comparison of results with other research, the definition of IT project success developed by the Standish Group (Standish Group, 1994, 1999, 2009) was utilized with minor modifications:

1. Project completion and implementation

2. Project performance against schedule plan and goals

3. Project performance against cost budget and goals

4. Project performance against scope plan and goals

These elements are graphically depicted in Figure 8. In order to compensate for the tendency of complex projects to experience greater change in scope, budget, and schedule than do less complex projects (Jiang, et al., 2002; J. Johnson, 2006), project success was measured against the original project goals and objectives (baseline 1) as well as against final project goals and objectives (baseline n).

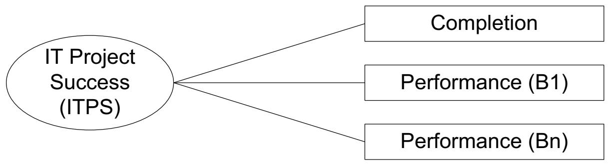


Figure 8. Elements of IT project success.

The conceptual model is summarized in Figure 9 which depicts the overall hypothesized relationships between ITPCx, ITPCn, and ITPS.

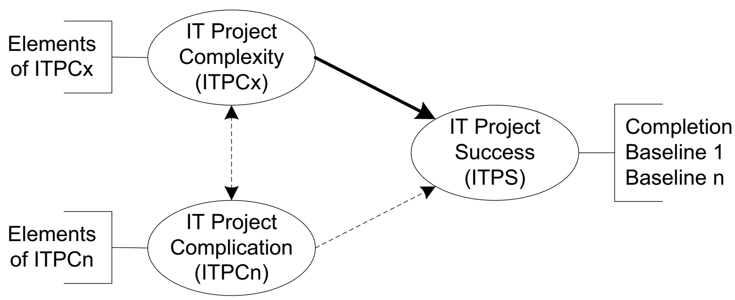


Figure 9. The IT project complexity and complication (PCC) model.

The following section describes the conversion of the conceptual model to operational constructs, elements, and factors.

Operational Definitions

In order to define and measure constructs for IT project complexity, IT project complication, and IT project success, elements and factors were analyzed and synthesized from existing literature (Hass, 2009; Standish Group, 1994, 1999, 2009; White & Fortune, 2002). The construct element table (see Table A1 in Appendix A) shows the sources, factors, and scales for the construct elements, and cross-references survey questions with the construct elements and factors. Independent variables are ITPCx (X1) and ITPCn (X2), and the dependent variable is ITPS (Y). In Figure 10, these variables are depicted graphically. In the following sections, the approach used to operationalize these variables is described.

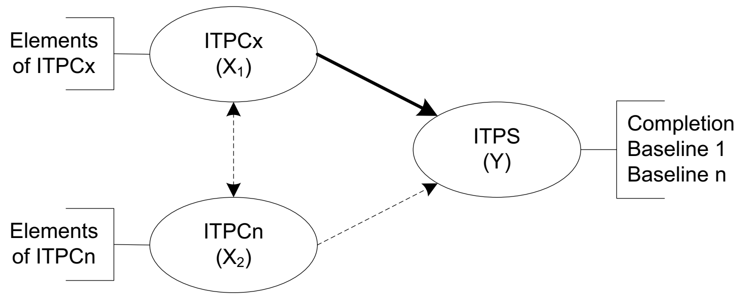


Figure 10. Independent and dependent variable constructs and elements.

Independent variable construct X_1: IT project complexity (ITPCx). Xia and Lee (2004, 2005) and Kim and Wilemon (2003, 2009) assessed project complexity with models incorporating organizational and technological complexity, structural and dynamic complexity, and technological, market, development, marketing, and organizational and inter-organizational complexity. Hass (2007a, 2007b, 2009) developed a more comprehensive project complexity model incorporating 11 categories of project complexity dimensions. The elements and factors used in this study to operationalize project complexity are described below.

ITPCx elements and factors. Hass (2009) assessed each factor contributing to project complexity on scales consisting of three descriptive categories. In order to enable data analysis through the use of normal statistics and correlation testing, these factors were converted from three-point ordinal category scales to five-point ordinal Likert-type scales (D. R. Johnson & Creech, 1983; Zumbo & Zimmerman, 1993). Conversion from the three-point ordinal category scales to five-point ordinal Likert-type scales was performed by analyzing and separating the components of each of the Hass project complexity dimensions, synthesizing a unidimensional description of each component, and then formulating a five-point Likert-type scale measuring agreement with each description (Likert, 1932).

Survey questions measuring ITPCx include questions 4.1 through 4.14. To minimize non-response and coverage errors, all survey questions assessing these factors require an answer, and also include a response indicating the question is not applicable or the answer is unknown (Dillman, 2000).

Project objectives, opportunity, and solution. Hass (2009) used a single three-category ordinal scale for clarity of problem, opportunity, and solution. In the current study, this dimension was separated into three elements and five factors, and subsequently measured on five-point ordinal Likert-type scales. Clarity of project objectives (ITPCx1) was measured by survey question 4.1. The project opportunity or problem (ITPCx2) was assessed by two factors including clarity and understandability (ITPCx2a), measured by survey question 4.2a; and familiarity to the project team (ITPCx2b), measured by survey question 4.2b. The project solution or technology (ITPCx3) was also assessed by two factors including familiarity to the project team (ITPCx3a), measured by survey question 4.3a; and availability at the time the project started (ITPCx3b), survey question 4.3b. Question responses measured agreement with a descriptive statement on a scale ranging from strong agreement to strong disagreement, and included an option to indicate the question is not applicable or the answer was unknown.

Project staffing, team, and methodology. Project staffing, team composition and prior performance, and project methodology were also defined by Hass (2009) using a single three-point ordinal category scale. In the current study, this scale was decomposed into three elements and five factors, measured on five-point ordinal Likert-type scales. Project staffing (ITPCx12) was measured by survey question 4.12. Attributes of the project team (ITPCx4) consisted of team experience (ITPCx4a), measured by question 4.5a; and prior team performance (ITPCx4b), measured by question 4.5b. The project methodology (ITPCx5) was assessed by its formality (ITPCx5a) in survey question 4.6a, and its consistency with other projects in the organization (ITPCx5b) in survey question 4.6b. Survey questions for these elements and factors measured agreement with descriptive statements on a scale ranging from strong agreement to strong disagreement, and included an option to indicate the question was not applicable or the answer was unknown.

Project schedule. While Hass (2009) combined the urgency and flexibility of project budget, schedule, and scope into a single three-point ordinal scale, literature reviewed for this study indicated that the project schedule had greater potential to cause complex project behavior than did the project scope or budget (Arthur, et al., 1997; Cilliers, 1998; Durlauf, 1997). Accordingly, the project schedule (ITPCx6) was treated in this study as an element of project complexity, while the scope and budget were treated below as elements of project complication. Attributes of the project schedule particularly likely to increase project complexity (Cilliers, 1998) included the original schedule's reasonableness (ITPCx6a) and flexibility (ITPCx6b), which were measured by survey questions 4.4a and 4.4b, respectively. As previously described, survey questions were formulated with five-point ordinal Likert-type scales measuring agreement with descriptive statements on scales ranging from strong disagreement to strong agreement, including the option to indicate a question was not applicable or an answer was unknown.

Project requirements. Hass (2009) assessed project requirements simultaneously on dimensions of volatility, risk, and complexity. For the purposes of this study, attributes of project requirements were treated as a single element (ITPCx7) comprised of clarity (ITPCx7a) and stability (ITPCx7b), measured respectively by survey questions 4.7a and 4.7b. Complexity of requirements was treated as a separate element defined below as IT complexity. Consistent with other elements, survey questions addressing project requirements were structured with five-point ordinal Likert-type scales measuring agreement with descriptive statements on scales ranging from strong disagreement to strong agreement, and included the option to indicate a question was not applicable or an answer was unknown.

Project environment. Hass (2009) utilized two separate multi-factor elements to evaluate the project environment. In the current study, these factors were combined into one element (ITPCx8) with six factors. Political importance (ITPCx8a), strategic importance (ITPCx8b), stakeholder diversity (ITPCx8c), external dependencies (ITPCx8d), regulatory change (ITPCx8e), and legal exposure (ITPCx8f) were measured by survey questions 4.13a through 4.13f. Question responses were presented on five-point Likert-type scales measuring the degree to which each environmental characteristic affected the project, ranging from very low to very high, and included the option to indicate the question was not applicable or an answer was unknown.

IT complexity. Two separate Hass (2009) elements also were used to address IT complexity. Factors of IT complexity and requirements volatility were combined in the current study into one element for IT complexity (ITPCx9) with two factors: degree of IT complexity (ITPCx9a) measured by survey question 4.14a, and degree of IT innovation (ITPCx9b), measured by survey question 4.14b. Survey questions were structured with five-point Likert-type response scales measuring the degree to which each factor was exhibited on the project, ranging from very low to very high, and included the option to indicate the question was not applicable or an answer was unknown.

IT integration. IT integration was combined with IT complexity in the Hass (2009) model, however in the current study a separate element was used for IT integration (ITPCx13), measured by survey question 4.11. Question responses were measured on a five-point Likert-type scale determining the number of interfaces to other systems included in the project scope/design. Question responses ranged from zero to seven or more, and included the option to indicate the question was not applicable or an answer was unknown.

Technological change. Hass (2009) assessed change to commercial practices, including technology development and delivery, as a single element of project complexity. In the current study, this element was simplified to technological change (ITPCx10), measured by survey question 4.10. The survey question was structured with five-point Likert-type response scales measuring the proportion of technological change exhibited on the project, ranging from very low to very high, and included the option to indicate the question was not applicable or an answer was unknown.

Organizational change. Hass (2009) assessed organization change by the number of business processes affected and the extent of organizational change. In the current study, organizational change (ITPCx11) was comprised of the proportion of business processes affected (ITPCx11a), measured by survey question 4.8, and extent of organizational change caused by the project (ITPCx11b), measured by survey question 4.9. Survey questions for both factors were structured with five-point Likert-type response scales measuring the proportion of business processes affected and the extent of organizational change, respectively, ranging from very low to very high, and included options to indicate the questions were not applicable or answers were unknown.

In the following section, the method used to aggregate the factor and element scores to a construct score for ITPCx is described.

ITPCx factor and element aggregation. In data analysis, the factors and elements of ITPCx were aggregated to define the construct for ITPCx using the aggregate construct approach described by Edwards (2001). Factor-level aggregation was performed for elements with two or more factors by summing scores on individual factors with equal weight for each factor, then dividing by the number of factors to obtain an aggregated mean score for each multi-factor element. Element-level aggregation was then performed by summing each element score with equal weight, and dividing by the number of elements to obtain an aggregated mean score for the construct. While data analysis may apply weights empirically derived from correlations among the elements, initial construct element aggregation with equal weights is a common practice in organizational research (Edwards, 2001). Figure 11 graphically depicts the factors and elements aggregated for the ITPCx construct.

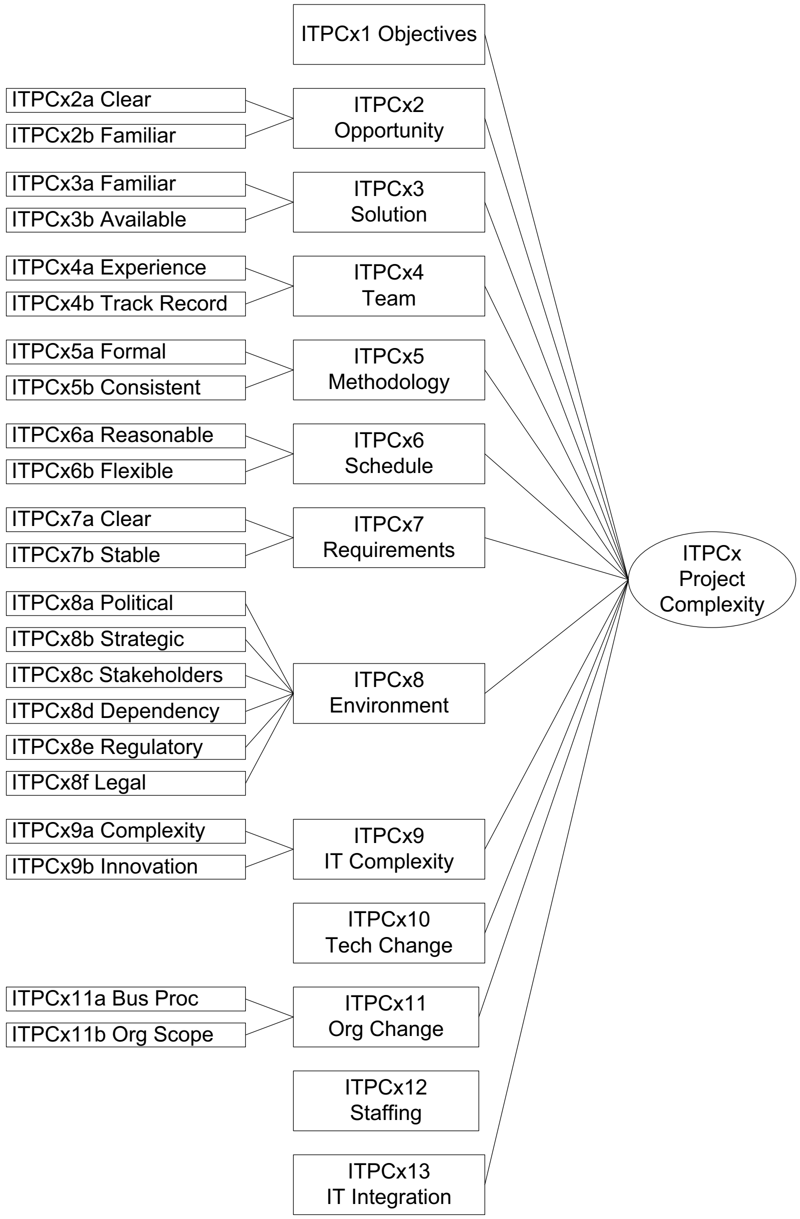


Figure 11. ITPCx factor and element aggregation schema.

Independent variable construct X_2: IT project complication (ITPCn). While the Hass (2007a, 2007b, 2009) model did not distinguish between project complexity and project complication, this distinction was critical for the current study. Analysis of the project characteristics defined in the Hass (2007a, 2007b, 2009) model using the definitions of complexity and complication developed by Cilliers (1998) resulted in the following elements and factors of IT project complication. IT project complication was measured by survey questions 5.1 through 5.11.

ITPCn elements and factors. In data analysis, the following elements and factors were aggregated to define the construct for ITPCn. As described in the section defining operational variables for IT project complexity, these elements and factors were converted from three-category ordinal scales used by Hass (2009) to five-point ordinal Likert-type scales. To minimize non-response and coverage errors, answers to all survey questions assessing these factors were required, but included a response indicating the question was not applicable or the answer was unknown (Dillman, 2000).

Project leadership. Hass (2009) utilized a single three-point ordinal category scale to assess team composition, project leader competence and performance, contract complexity, and contractor performance. For this study, attributes of project leadership were treated as a single element (ITPCn1) comprised of project leader experience (ITPCn1a) and project leader competence (ITPCn1b), measured respectively by survey questions 5.1a and 5.1b. Contract complexity and contractor performance were assessed separately below. Survey questions addressing project leadership were structured with five-point ordinal Likert-type scales measuring agreement with descriptive statements on scales ranging from strong disagreement to strong agreement, and included the option to indicate a question was not applicable or an answer was unknown.

Project duration. Hass (2009) also developed a single element for project duration and cost. In this study, project duration was considered a distinct element (ITPCn2), measured by survey question 5.2 on a five-point ordinal Likert-type scale ranging from less than three months to more than 12 months, with an option to indicate the question was not applicable or the answer was unknown. Project cost was treated as a separate element and is described below.

Project cost/budget. Project cost (ITPCn3) was comprised of two factors. Original project budget (ITPCn3a) was measured by survey question 5.4 on a five-point ordinal Likert-type scale with responses ranging from less than $250,000 to more than $1,000,000. Budget flexibility (ITPCn3b) was measured by survey question 5.5 on a five-point ordinal Likert-type scale with responses ranging from very low to very high. Both survey questions addressing cost also had the option to indicate the question was not applicable or the answer was unknown.

Project team size. Hass (2009) used a single element to measure the project team size. The current study also measured project team size (ITPCn3) as a single element with survey question 5.3 on a five-point ordinal Likert-type scale, with responses ranging from less than three members to more than 15 members, and an option to indicate the question was not applicable or the answer was unknown.

Scope flexibility. While Hass (2009) combined urgency and flexibility of cost, time, and scope into a single element, the current study measured scope flexibility (ITPCn5) as a single element. In survey question 5.6, a five-point ordinal Likert-type scale was used with responses ranging from very low to very high, and not applicable or unknown.

Technology scope. Hass (2009) addressed technology scope within a three-point ordinal category scale measuring the level of organizational change. In this study, technology scope (ITPCn6) was measured by survey question 5.7 with a five-point ordinal Likert-type scale with responses ranging from 0% to 100%, and not applicable or unknown.

Organizational support. Hass (2009) did not distinguish between organizational change and organizational support for the project. In this study, organizational support (ITPCn7) was comprised of two factors, executive support for the project (ITPCn7a) measured by survey question 5.8a, and user support (ITPCn7b) measured by survey question 5.8b. Both survey questions were formulated with five-point ordinal Likert-type scale with responses ranging from very low to very high, and not applicable or unknown.

Organizational units affected. In addition to organizational support, the current study measured how many organizational units were affected by the project (ITPCn8). Survey question 5.9 was used to measure this on a five-point ordinal Likert-type scale with responses ranging from none to more than 7, with an option to indicate the question was not applicable or the answer was unknown.

Contracts. While Hass (2009) considered contracts and contractors together with other elements, in the current study project contracts and contractors (ITPCn9) were assessed by three factors. The number of contracts used (ITPCn9a) was measured by survey question 5.10 on a five-point ordinal Likert-type scale with responses ranging from none to more than 7. Contractor familiarity (ITPCn9b) and contractor performance (ITPCn9c) were measured by survey questions 5.11a and 5.11b with five-point ordinal Likert-type scales measuring agreement with descriptive statements on a scale ranging from strong disagreement to strong agreement, with options to indicate the questions were not applicable or the answers were unknown.

Factor and element aggregation for IT project complication is described in the following section.

ITPCn factor and element aggregation. As described for ITPCx, the elements and factors of ITPCn were aggregated according the aggregate construct approach described by Edwards (2001). Factor-level aggregation were performed by summing factor scores with equal weighting, then dividing by the number of factors to obtain an aggregated mean score for each multi-factor element. Element-level aggregation was then performed by summing each element score with equal weight and dividing by the number of elements to obtain an aggregated mean score for the construct. Subsequent data analysis considered applying weights empirically derived from correlations among the elements. Figure 12 graphically depicts the factors and elements aggregated for the ITPCn construct.

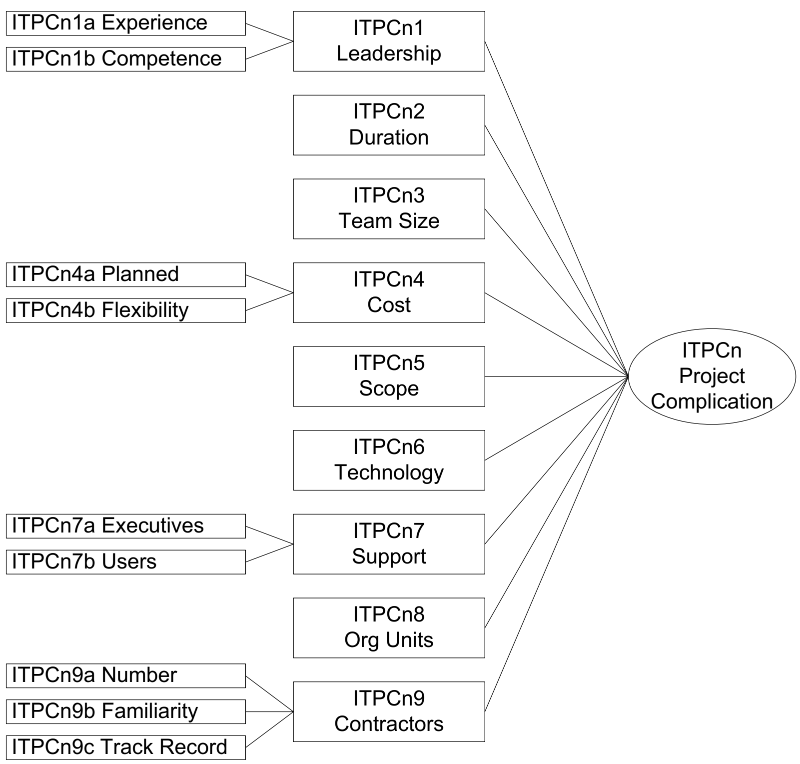


Figure 12. ITPCn factor and element aggregation schema.

Dependent variable construct Y: IT project success (ITPS). While IT project success has been defined in numerous ways (Baccarini, 1999; Glass, 2006b; Standish Group, 2009), this study utilized the definition developed by the Standish Group (1994, 1999, 2009) in order to facilitate potential comparison of study results. The definition was based on the triple constraint dimensions of schedule, budget, and scope, but also assessed whether the project was completed and implemented. In addition, project success was measured against the original project goals and objectives as well as against final project goals and objectives (Standish Group, 1994, 1999, 2009). IT project success was measured by survey questions 6.1 through 6.6.

ITPS elements and factors. Scales used by the Standish Group (1994, 1999, 2009) were markedly skewed away from project success toward schedule and budget overruns and scope under-delivery. However, in order to facilitate comparison of project success results with prior research, the Standish scales were adapted in the current study to five-point ordinal Likert-type scales with minimal modification. To reduce non-response and coverage errors, answers to all survey questions assessing project success factors and elements were required, but included a response indicating the question was not applicable or the answer was unknown (Dillman, 2000).

Project completion. Standish Group (1994, 1999) measured project success using a combination of two-category binomial scales and six-point ordinal Likert-type scales. Project completion was measured by survey questions defining project failure as cancellation of the project before it was completed or implemented. In the current study, the element project completion (ITPS1) was comprised of factors for the degree of project completion (ITPS1a) and the degree of project implementation (ITPS1b). These factors were measured by survey questions 6.1 and 6.6, respectively, utilizing five-point ordinal Likert-type scale with responses ranging from less than 25% of the project scope completed or implemented to more than 100% of the project scope completed or implemented, and not applicable or unknown. Conversion of the Standish Group (1994, 1999) two-category binomial scales and six-point ordinal Likert-type scales was performed by dividing the ranges covered by the Standish scales into five equal proportions and assigning them to the five ranges used in the current study.

Project performance against original plan and goals (Baseline 1). Standish Group (1994, 1999) measured project success against the original project plans and goals only. Since effective project management practices include adjusting the project baseline as the project is progressively elaborated (Project Management Institute, 2008a), the current study considered project performance against both the original plans and goals or baseline 1, and the final, adjusted plans and goals or baseline n. Project performance against the original plans and goals (ITPS2) was comprised of performance against the original schedule (ITPS2a), performance against the original budget (ITPS2b), and performance against the original scope (ITPS2c). These factors were measured by survey questions 6.2a, 6.2b, and 6.3 respectively. In survey questions 6.2a and 6.2b measuring schedule and budget performance, five-point ordinal Likert-type scale were used with responses ranging from on or under the original plan to more than 100% over the original plan. In survey question 6.3 measuring scope performance, a five-point ordinal Likert-type scale was used with responses ranging from less than 25% of the original plan to 100% or more of the original plan. All three questions included responses for not applicable or unknown.

Project performance against final plan and goals (Baseline n). Project performance against the final plans and goals (ITPS3) was comprised of performance against the final schedule (ITPS3a), performance against the final budget (ITPS3b), and performance against the final scope (ITPS3c), measured by survey questions 6.4a, 6.4b, and 6.5, respectively. In survey questions 6.4a and 6.4b, five-point ordinal Likert-type scale were used with responses ranging from on or under the final plan to more than 100% over the final plan. In survey question 6.5, a five-point ordinal Likert-type scale was used with responses ranging from less than 25% of the final plan to 100% or more of the final plan. As above, all three questions included responses for not applicable or unknown.

Factors and elements comprising IT project success were aggregated similarly to those used to define IT project complexity and IT project complication.

ITPS factor and element aggregation. As described for ITPCx and ITPCn, factors and elements of ITPS were aggregated according the aggregate construct approach described by Edwards (2001). Factor-level aggregation was performed by summing factor scores with equal weighting, then dividing by the number of factors to obtain an aggregated mean score for each multi-factor element. Element-level aggregation was then performed by summing each element score with equal weight and dividing by the number of elements to obtain an aggregated mean score for the construct. Subsequent data analysis considered applying weights empirically derived from correlations among the elements. Figure 13 graphically depicts the factors and elements aggregated for the ITPS construct.

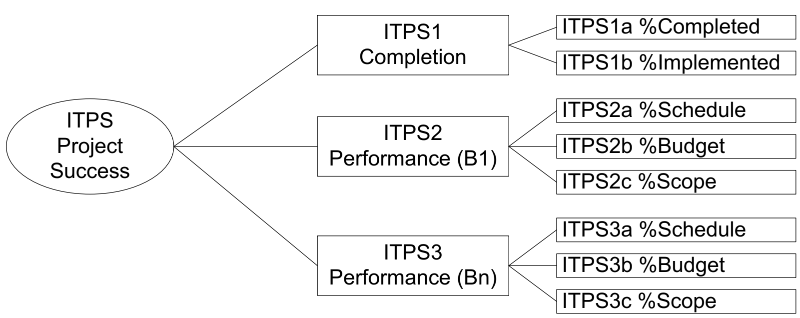


Figure 13. ITPS factor and element aggregation schema.

Sample and Setting

The target population for the study was IT project management practitioners in the U.S. For purposes of availability and accessibility, the study population was limited to members of the Project Management Institute's Information Systems Community of Practice (PMI IS CoP), a U.S.-based project management professional organization.

Study Population

The PMI IS CoP (formerly known as the PMI-ISSIG) has over 15,000 members worldwide, approximately 40% to 50% of whom reside in the U.S. (Mishra, et al., 2009; PMI-ISSIG, 2008). Since the stated objectives of the PMI IS CoP include advancing the practice of IS and IT project management, and the Project Management Institute is engaged in promoting and advancing the professional certification of project managers (PMI-ISSIG, 2008; PMI IS CoP, 2011), it is possible that members of the PMI IS CoP are more advanced in project management knowledge and practices than non-members. While this may have limited the generalizability of the findings to the target population of U.S. IT project management practitioners, it did provide the opportunity to assess the state of the art in current U.S. IT project management practice.

Other studies have also used this population to investigate current IT project management practice. Wallace, Keil, and Rai (2004) considered a population of 3,800 U.S. members of the PMI-ISSIG e-mail list and an additional 7,200 members of a PMI-ISSIG e-mail newsletter subscription list. Xia and Lee (Xia & Lee, 2005) limited their study to (a) North American PMI-ISSIG members, (b) practicing project managers, and (c) those who had recently completed an ISDP project; the total resulting number of potential survey respondents was 1,740. Mishra, et al. (2009) extended their study population to members of the PMI-ISSIG and the PMI New Product Development Special Interest Group (PMI-NPDSIG) from all geographic locations, resulting in a study population of approximately 11,000 individuals.

Sampling Frame and Sampling Methods

Restricting the study population to U.S. members of the PMI IS CoP resulted in a study population of approximately $N = 6{,}000$. Probability sampling of a study population increased the validity of generalizing to the target population (Cooper & Schindler, 2003). In order to maximize validity, the PMI IS CoP allowed an unrestricted 100% sample of the study population. Power analysis (Kraemer & Thiemann, 1987; Murphy & Myors, 2004) performed using G*Power 3 software (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007) to determine a priori sample size for bivariate normal correlation indicated a minimum sample size of $n = 115$ with alpha α error probability = .05, power (1-β error probability) = .95, and correlation $\rho = .30$.

For similar studies (Mishra, et al., 2009; Wallace, et al., 2004; Xia & Lee, 2005), the PMI IS CoP has collaborated with researchers in providing samples based on selection criteria such as location, industry, and certification status. For the purposes of this study, survey invitations were sent by e-mail to all members of the PMI IS CoP, a 100% probability sample, resulting in a total sample size of approximately $N = 6{,}000$ U.S. IT project managers. Response rates to similar studies (Mishra, et al., 2009; Wallace, et al., 2004; Xia & Lee, 2005) indicated a reasonable expected response rate of 6% to 15%, resulting in a range of 360 to 750 expected responses.

Initial survey response rates were higher than expected, surpassing the minimum sample size for statistical validity of $n = 115$ after the fourth day of the 30-day data collection period (see Figure 14). After 10 days, a total of 208 qualified responses (88.6% of the total) had been received, obviating the need for follow-up e-mail reminders. After 20 days, 228 responses (97.0%) had been received, and at the end of the data collection period on day 30, a total of 235 responses had been received. This represented approximately 3.9% of the 6,000 U.S.-based members of the PMI IS CoP, a response rate lower than that reported for similar studies with response rates ranging from 6% to 15% (Mishra, et al., 2009; Wallace, et al., 2004; Xia & Lee, 2005), but more than twice the minimum sample size indicated by power analysis. The cumulative response trend line in Figure 14 indicates the strong initial response rate followed by significant slowing of responses after 5 to 6 days.

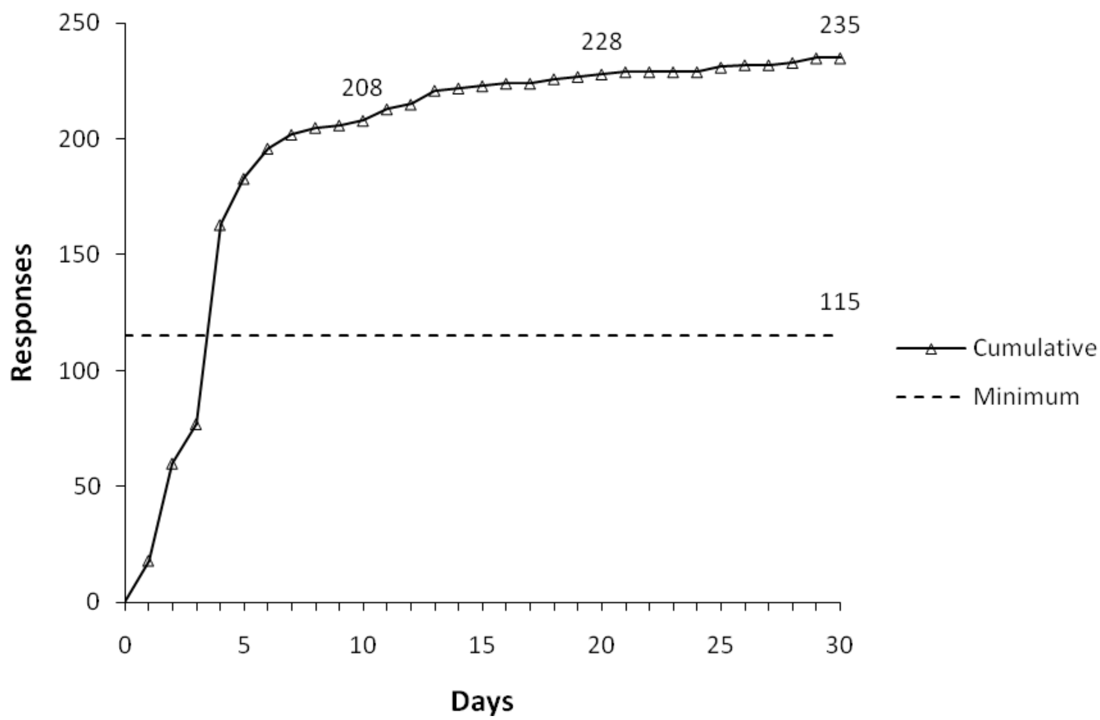


Figure 14. Cumulative survey responses.

In spite of a lower response rate than expected (n = 235), post hoc power analysis with alpha α error probability = .05, correlation ρ = .30, and sample size of n = 235 indicated power (1-β error probability) = .9989, greater than the sample power (1-β error probability) = .95 for the minimum sample size of n = 115 indicated by a priori power analysis.

Participant Access

Participant access was obtained through e-mail invitations to participate in the online survey, sent directly by the IS CoP leadership to the members selected in the sample. A sample e-mail inviting participation is included in Appendix B. Survey participation was solicited by direct e-mail invitation only with no publicly posted survey links or addresses. The survey was hosted by SurveyMonkey, an online survey provider, for a period of 30 days. Survey responses were tallied daily and response trends were evaluated after 10 days and 20 days. A plan was in place to send additional e-mail reminders to all invited participants and extend the survey period if sufficient responses had not been received to meet the minimum effective sample size of n = 115.

Setting

IT project management practitioners belonging to the PMI IS CoP are a self-selected group that is typically interested in promoting the field of IT project management (PMI-ISSIG, 2008; PMI IS CoP, 2011). While the setting is membership-based and does not include a random sample of all U.S. IT project managers, it has previously been considered useful for researching current practice in the field. Precedent exists for conducting IT project management research in this setting (Mishra, et al., 2009; Wallace, et al., 2004; Xia & Lee, 2005), and PMI supports an active and extensive research agenda (Project Management Institute, 2006).

Instrumentation and Measures

No existing instruments assessing the relationships between IT project complexity, complication, and success were identified in the literature review. Data collection was performed through an Internet survey created by the researcher. The use of Internet survey methods in information systems research is well documented and supported (Pinsonneault & Kraemer, 1993; Sivo, Saunders, Chang, & Jiang, 2006). Validity and reliability of the survey instrument are addressed in the following sections.

Survey Instrument

The survey instrument is included in Appendix C. Survey design was consistent with best practices for online surveys (Dillman, 2000; Dillman, et al., 2001; Dillman, Tortura, & Bowker, 1998). The survey was hosted by SurveyMonkey. To minimize non-response and coverage errors, answers to all survey questions assessing elements and factors for ITPCx, ITPCn, and ITPS were required, but also included a response indicating the question was not applicable or the answer was unknown (Dillman, 2000). Survey sections addressing each research question are indicated in Table 4.

The survey was developed specifically for the study and had not been previously validated; therefore both field testing and pilot testing of the survey were indicated. Field testing was performed in two phases, including a qualitative review in a seminar on agile project management methods, and a quantitative review using a sample of the instrument and a brief feedback survey. Pilot testing was performed by posting invitations in the LinkedIn online PMI IS CoP professional networking group soliciting volunteers for a research survey on IT project complexity.

Table 4

Survey Sections Addressing Research Questions

	Research questions addressed by constructs			
Survey section	RQ1	RQ2	RQ3	RQ4
IT project complexity	ITPCx	ITPCx	None	ITPCx
IT project complication	ITPCn	None	ITPCn	ITPCn
IT project success	None	ITPS	ITPS	ITPS
Demographics	Additional analysis	Additional analysis	Additional analysis	Additional analysis

Field Testing

The survey instrument was field-tested using a two-phase qualitative and quantitative review process. In the first phase of the field test, 31 participants of a PMI-hosted seminar on agile project management were asked to complete a paper version of the survey as part of an exercise in assessing project complexity, project complication, and project success. A scoring key was provided so the testers could calculate summary scores for project complexity and complication, but testers were not asked to submit the completed survey document. Testers were asked to comment verbally on the ease of use of the survey, the clarity of the survey questions, the effort required to complete the survey, and the perceived accuracy of the project complexity and complication scores. Feedback was incorporated into minor survey redesign and rewording of some of the instructions and survey questions.

In the second phase of the field test, 12 experienced IT project management practitioners were asked to review an online version of the survey instrument hosted by

SurveyMonkey. After reviewing the instrument, field test participants were asked to complete a brief survey assessing degree of agreement with several statements about the survey measured on five-point ordinal Likert-type scales. Feedback questions were intended to assess whether the survey instructions were clear and the survey questions were unambiguous and easy to answer. Results from the field test feedback were used to make additional minor revisions to the survey design, instructions, and questions.

Pilot Study Testing

Survey pilot testing is indicated when a quantitative survey instrument has not been previously validated (Dillman, 2000; Litwin, 1995). Since pilot testing required collecting actual survey data, IRB approval was obtained before pilot testing was performed. To solicit pilot test participants, invitations were posted on the LinkedIn PMI IS CoP group page inviting members to participate in a pilot test of a new survey for a study investigating IT project complexity. The researcher is a member of this group and has responded to several previous invitations to participate in similar studies.

The PMI IS CoP LinkedIn group has approximately 6,800 members (LinkedIn, 2009) who are also members of the PMI IS CoP. Pilot survey responses in the range of 100 to 200 participants are occasionally sought for large population survey pilot testing (Dillman, 2000); however, a pilot study with 35 to 40 participants yields a confidence interval CI > 95% for hypothesis testing (Johanson & Brooks, 2010).

An abbreviated schedule allowing 10 days for responses and following up with additional invitations was utilized for the pilot testing process. No participant identification information, including any representation of name, e-mail address, or the IP address of the computer used to complete the survey was gathered during the pilot test.

After completing the pilot survey, pilot study participants were requested to complete the same brief survey used during field testing to assess whether survey instructions were clear and survey questions were unambiguous and easy to answer.

Using the pilot survey results, the following analyses were performed on the survey instrument (Dillman, 2000):

1. Does the response rate to the pilot survey indicate the actual survey response will be adequate?
2. Are the responses for scalar questions distributed across the categories or clustered?
3. Do any of the construct elements correlate in ways that will allow further analysis? Do any construct elements correlate to such a high degree that they may be combined or eliminated?
4. Are any survey questions exhibiting significantly higher "not applicable or unknown" response rates?

Appropriate confidentiality measures were followed with pilot test data. No data collected during pilot testing was used in the actual study data analysis.

Pilot Study Results

Pilot survey responses (n = 42) exceeded the minimum desired response rate of 35 to 40 participants. Responses for all scalar questions were well-distributed across the five-point Likert-type scales. Correlations between factors and elements of ITPCx, ITPCn, and ITPS appeared reasonably reliable.

Response rate. During the 10 day pilot data collection period, a total of 42 responses were received. Response rates to the initial invitation posted in the PMI IS

CoP LinkedIn group indicated that follow-up reminders would be required to reach the desired 35 to 40 responses. Reminders were posted daily, and by the end of the advertised data collection period, sufficient responses had been received.

While follow-up reminders to the pilot study invitation were required to reach desired response levels, this did not necessarily indicate response to the actual survey would be low. Group postings in professional networking sites such as LinkedIn groups typically exhibit significantly lower response rates than do direct e-mail invitations to the same population (Couper & Miller, 2008).

Response distribution for scalar questions. The survey included 48 questions with five-point ordinal Likert-type scales. Table 5 shows the number of scalar questions associated with each construct and the summary distributions of pilot survey response ranges and standard deviations for each construct.

Table 5

Pilot Survey Scalar Question Response Ranges and Standard Deviations

		Range				*SD*	
Construct	Scalar Questions	1	2	3	4	< 1	>= 1
ITPCx	26	0	0	4	22	2	24
ITPCn	14	0	0	2	12	3	11
ITPS	8	0	0	0	8	0	8
Total	48	0	0	6	42	5	43

Note: $N = 42$ pilot survey responses.

Pilot survey responses for the scalar questions were reasonably distributed. Six of the 48 pilot survey scalar questions had a response range of 3; the remaining 42 scalar questions had a response range of 4, the maximum range for a five-point Likert type scale. In addition, only five of the scalar questions exhibited a response range standard deviation $SD < 1.0$, while 43 scalar questions had a response range standard deviation $SD >= 1.0$. These results indicate no issues with scalar question response distribution.

Construct element correlation. Correlation between factors and elements of ITPCx ranged from $r = .639$, $p < .001$ to $r = -.373$, $p < .05$, indicating a broad range of correlations, both positive and negative, between factors and elements with varying degrees of statistical significance. Correlations between factors and elements of ITPCn ranged from $r = .736$, $p < .001$ to $r = -.320$, $p < .05$. Correlations between factors and elements of ITPS ranged from $r = .714$, $p < .001$ to $r = -.312$, $p < .1$. These results indicated reasonable reliability for correlation analysis (J. Cohen, 1988, 1992).

"Not applicable or unknown" response rates. Pilot study testing was also intended to determine if any questions exhibited unusually high non-response rates. Answers to all 48 survey questions assessing elements and factors for ITPCx, ITPCn, and ITPS were required and included a response indicating the question was not applicable (N/A) or the answer was unknown. Twenty of the 48 questions had no N/A or unknown responses; 38 had N/A or unknown response rates less than 10%. Five questions had N/A or unknown response rates greater than 15%. Three of these questions were intended to assess the ITPCn construct, and the other two assessed the ITPS construct. No questions assessing ITPCx had N/A or unknown response rates greater than 5%. While high non-response rates on pilot survey questions can be indicative of confusing or contradictory questions (Dillman, 2000), additional data from the pilot survey feedback questions indicated there were no significant issues with the clarity and ease of answering the questions. All questions with N/A or unknown response rates above 10% were intended to collect information about specific project characteristics which may be less commonly measured than other project characteristics, and therefore may have led to higher non-response rates for those questions.

Data Collection

Data collection for the study was performed through an Internet survey with e-mail invitations. Cross-contamination of pilot study data and actual survey data was prevented by requiring survey participants to respond to a survey question indicating whether they had participated in the pilot study. Three quantitative constructs were investigated: IT project complexity (ITPCx), IT project complication (ITPCn), and IT project success (ITPS). Data for ITPCx was collected through survey questions asking participants to rate the project under consideration on five-point ordinal Likert-type scales against several factors suggested to contribute to IT project complexity. Data for ITPCn was collected through survey questions asking participants to rate the project under consideration on five-point ordinal Likert-type scales against several factors suggested as contributing to IT project complication. Data for ITPS was collected through survey questions asking participants to evaluate the success of the project under consideration against project success criteria measured on five-point ordinal Likert-type scales.

Demographic data was also gathered through survey questions requesting a selection be made from a list of alternatives or an additional entry be made through a category for other responses. Survey questions used for demographic data were derived from other studies to increase the potential for comparison of results. Categories for industry sector, project type, number of employees, title, and role were adapted with minimal changes from White and Fortune (2002); categories for annual revenue were adapted from Standish Group (1994):

1. Industry sector
2. Annual revenue or operating budget
3. Number of employees
4. Project type
5. Your title
6. Your role on the project
7. Project management certification
    a. You
    b. The project manager, if you were not the project manager

The additional factor for project management certification was included for informational purposes. The sample strategy addressed the inclusion of certified and uncertified members of the study group.

Data Analysis

Since existing models of IT project complexity did not differentiate between complexity and complication, it was determined that for the purposes of this study, constructs and elements for ITPCx and ITPCn would be developed by analyzing existing models and categorizing contributing factors. Although structural equation modeling and confirmatory factor analysis were beyond the scope of the study, Cronbach's alpha was used to determine internal consistency of the survey instrument and the constructs for ITPCx, ITPCn, and ITPS. The Kolmogorov-Smirnov (Bryman & Cramer, 2005;

Lehmann & Romano, 2005) and Shapiro-Wilk (Sen, 2002; Shapiro & Wilk, 1965) tests were performed to compare the observed frequencies of responses for elements of ITPCx, ITPCn, and ITPS against the normal distribution to assess goodness of fit and determine whether the ordinal data could be treated as interval data. Since results indicated that ITPS was not normally distributed, several transformations were tested and an inverse normal transformation using the ranking method was applied to create a normally distributed transform, NITPS (Solomon, 2008; Solomon & Sawilowsky, 2009). Chi-square analysis was then utilized to confirm relationships existed between the ITPCx, ITPCn, and ITPS constructs and the NITPS transform (Ness, 2005). Finally, Pearson's correlation coefficients and nonparametric correlations including Kendall's tau_b and Spearman's rho were determined and used to model the relationship between the dependent variable ITPS (Y), the two independent variables ITPCx (X_1) and ITPCn (X_2), and the interaction between them (X_1X_2) (SPSS, 2004).

Validity and Reliability

The validity of a research study is a measure of its general trustworthiness and reliability (Robson, 2002). Methods of assessing and improving validity have evolved extensively over the past several decades (Kane, 2001). Dimensions of validity can be grouped into two primary categories: internal validity or reliability, and external validity or generalizability. Campbell and Stanley (1963) introduced the concept of internal validity in their seminal paper on research in education in which they discussed several possible threats to validity, including history or the elapsed time between measurements of events, consistency of instrumentation, and--indirectly invoking the Heisenberg (1927) uncertainty principle--the effects of testing on the values of other tests. Aspects of internal validity considered in this study include design validity; content, criteria, and construct validity.

Selection bias was described by Campbell and Stanley (1963) as a component of internal validity, although it has been considered by other researchers as more salient to external validity (Berk, 1983; Winship & Mare, 1992). External validity is strongly affected by sample representativeness; identifying and obtaining a truly random and representative sample in organizational research is nearly impossible (Bryman, 1989; Schwab, 1985). However, careful sampling strategy can maximize external validity and generalizability (L. Cohen, Manion, & Morrison, 2007). External validity can also be affected by non-response bias (Armstrong & Overton, 1977; Sax, Gilmartin, & Bryant, 2003; Suchman & McCandless, 1940). If subjects who respond to an invitation to participate in a research study are not representative of the sample as a whole, then generalizability is further reduced. Methods used in this study to address internal and external validity are described in the following sections.

Internal Validity

The concept of internal validity is used to address whether the conclusions drawn in a study are reliable and are adequately supported by the design, the variables identified, the data analysis, metrics, constructs, and statistical methods (Cooper & Schindler, 2003). It can also be applied to the relationship between the study and existing theory (Arbnor & Bjerke, 1997). Design validity of quantitative correlational studies has been addressed by several authors (Cronbach, 1957; Fraenkel & Wallen, 1993; Mitchell, 1985). Due to the inability to control for environmental factors as in experimental research, the greatest threat to internal validity of correlational studies is the possibility of confounding variables correlated with either the independent variable X or the dependent variable Y, or both (Mitchell, 1985). This potential design weakness can be addressed through validity testing of the constructs used to measure the study variables (Drasgow & Miller, 1982). Available statistical methods include confirmatory factor analysis and Cronbach's alpha; the former was beyond the scope of this study, however, the latter was utilized.

Design validity. Cronbach (1957) described the origin of correlational research as an alternative to experimental research in the field of scientific psychology, pointing out that "what began as a mere summary statistic quickly became the center of a whole theory of data analysis" (p. 674). Cronbach further contrasted the two psychological research disciplines by suggesting that while experimental research controls situational variables, correlational methods can at best "study what man has not learned to control or can never hope to control" (p. 672). This skeptical view of the relative validity of correlational research has persisted. In the field of organizational research, Mitchell (1985) compared correlational and experimental validity and found systemic issues with internal validity of correlational research across a broad sample of 126 studies. In a more recent article on evidence-based practice in educational research, Thompson, Diamond, McWilliam, Snyder, and Snyder (2005) re-emphasized the gap between causal conclusions from randomized experiments and causal inferences from correlational analysis.

Correlational studies are inherently less reliable than experimental studies; however, methods exist to maximize their validity. Structural equation modeling (Jöreskog, 1969, 1970) uses factor and path analysis to interpret whether constructs can be considered correlated, linearly causal, or reciprocally causal. It was considered beyond the scope of this study due to the relative immaturity of the conceptual model and survey instrument. Cronbach's (1951) alpha (α) measures the consistency of survey questions, constructs, and construct elements. Primarily an indicator of construct validity, α is often used as a general indicator of internal reliability (Cortina, 1993).

Content, criteria, and construct validity. Content validity considers the extent to which data collection instruments contain a representative subset of the relevant subject matter (Cooper & Schindler, 2003). Content validity can be increased by broadening the sources investigated to identify and develop constructs and instruments used for measurements (Haynes, Richard, & Kubany, 1995). For the current study, an extensive literature review was performed to identify and compare existing constructs, elements, and factors of IT project complexity, IT project complication, and IT project success.

Criterion-related validity is concerned with the degree to which the selected measures can be used to identify correlations between the variables of interest. Measurement criteria are deemed to be valid if they exhibit relevance, freedom from bias, reliability, and availability (Cooper & Schindler, 2003). Relevance and freedom from bias were addressed in the current study by developing constructs and elements from the results of extensive literature analysis. Availability was addressed by performing data gathering through a hosted online survey to minimize the cost of data collection and maximize the sample size.

Constructs are conceptual representations abstracted from more observable characteristics of entities and used to study and explain observed phenomena (Morgeson

& Hofmann, 1999). In essence, constructs are used to measure attributes that cannot be measured directly. Construct validity refers to the degree to which empirical measurements correspond to the characteristics and phenomena of interest (Cronbach & Meehl, 1955; Drasgow & Miller, 1982; Schwab, 1980). Construct validity and reliability can be assessed with statistical methods. In this study, Cronbach's (1951) alpha was used to determine the internal consistency of the survey instrument and underlying constructs and elements. Construct validity can also be addressed through the use of confirmatory factor analysis and the assessment of interactions between observed characteristics and observation methods (Bagozzi, Yi, & Phillips, 1991). Such confirmatory factor analysis was beyond the scope of this study.

External Validity

External validity refers to the generalizability of study results beyond the study population (Arbnor & Bjerke, 1997). Generalizability of correlational studies is inherently less than that of experimental studies. Other factors affecting external validity of quantitative correlational studies include sample representativeness, selection effects, and non-response bias.

Sample representativeness. Generalizability of correlational research is affected by the degree to which a study sample is a representative random sample of the study population. Identifying and accessing a representative sampling frame for organizational research is often time-consuming and costly (Robson, 2002), therefore it is usually impossible to obtain a truly random and representative sample (Bryman, 1989; Schwab, 1985). Risks to external validity and generalizability can be reduced by effective sampling strategy, such as selecting a population that is accessible and one that has been used previously for similar studies (L. Cohen, et al., 2007). An accurate sampling frame and probabilistic sampling can further reduce bias and increase generalizability (Robson, 2002). The PMI IS CoP is a frequently-studied population that has traditionally responded well to invitations to participate in survey research, with response rates ranging from approximately 6% to 32% (Mishra, et al., 2009; Wallace, et al., 2004; Xia & Lee, 2005). A 100% probability sample of the study population of approximately N = 6,000 U.S. PMI IS CoP members was used to maximize the validity of generalizing to the target population of all U.S. IT project managers.

Selection effects. In sociological research, the opportunity for selection bias is significant. Citing such examples as the severity and frequency of wife battery, Berk (1983) illustrated the tendency for less serious events to be underrepresented simply because they are not reported or investigated. Selection bias occurs whenever a non-random sample of a survey population is chosen. Compounding selection effects, it is difficult to assess whether findings based on a non-random sample underestimate or overestimate the relationships between variables (Berk, 1983; Winship & Mare, 1992).

Heckman (1979) identified two primary sources of selection bias: self selection, or the tendency for research subjects to respond non-randomly; and researcher selection, the tendency of researchers to inadvertently prefer or exclude certain population members. Heckman also proposed a method for estimating selection bias using estimates of omitted data in linear regression that has been widely used in sociological research. In subsequent studies, weaknesses of Heckman's estimator (Stolzenberg & Relles, 1990, 1997) have been identified, reconfirming that since it is usually impractical, unethical, or illegal to use data gathering methods that force participants to respond, most samples in sociological research are biased.

Winship and Mare (1992) reviewed several additional techniques for identifying and estimating selection bias, and concluded that since existing models of selection bias were based on implicit assumptions about how selection occurs, no available technique could consistently eliminate such bias. Stolzenberg and Relles (1997) also concluded that intuition may be the only option remaining for determining the effects of selection bias, and its effects could be counterintuitive.

With no consistently reliable way to detect and correct selection bias, a careful selection process is essential. The sampling frame used in this study, the PMI IS CoP, presented the possibility of selection bias since only those IT project managers who were members of PMI and the PMI IS CoP could be surveyed in this manner, and PMI members are typically self-selecting; however, the population has been used extensively for similar studies (Mishra, et al., 2009; Wallace, et al., 2004; Xia & Lee, 2005). Although regression techniques exist to estimate responses without selection bias, their use was beyond the scope of this study, and any generalization of conclusions from this study, although potentially useful, must be considered in the context of a potentially biased sample.

Non-response bias. In addition to selection bias, external validity of non-experimental survey research is also affected by non-response bias (Armstrong & Overton, 1977; Sax, et al., 2003; Suchman & McCandless, 1940). Whenever the possibility exists that subjects who respond to an invitation to participate in a research study are not representative of the sample as a whole, then generalizability is further reduced.

Early research into the efficacy of sending survey questionnaires by mail identified non-response as a potential concern. Suchman and McCandless (1940) found different initial response rates to mailed surveys by degree of familiarity and personal experience with the survey topic, as well as the topic's importance to the research subject. They also received a greater total response from sending follow-up mailings to those who had not responded than that which was obtained from using an initial sample twice the size. The enhanced response rate also increased sample representativeness, leading them to suggest that rather than increasing sample size to maximize response, researchers could increase overall response and representativeness by sending reminders to non-responders. More recently, Xia and Lee (2005) used follow-up e-mail reminders to increase response to a survey sent to a sample drawn from the same sampling frame as the current study.

Armstrong and Overton (1977) suggested several methods for estimating non-response bias including comparison with known population characteristics and estimation of selection effects through linear extrapolation. Sax, et al. (2003) compared response rates to paper surveys and web surveys among college students, citing lower cost among the benefits of web surveys but claiming less reliable generalizability for web surveys than paper surveys due to Internet access inequalities, security concerns, and survey design differences. Members of the PMI IS CoP are typically accustomed to electronic communication and have responded well to similar surveys in the past.

In a study of the effects of information overload on the recognition of software project risk, Pennington and Tuttle (2007) tested for non-response bias by separating early and late responders and performing analyses of variance (ANOVAs) on all dependent variables. They found no significant variances across any range of response times. Sivo, Saunders, Chang, and Jiang (2006) specifically addressed the validity of inferences drawn from information systems survey research with low response rates. Reviewing methods used to estimate and reduce non-response bias in six IS research journals, they recommended Dillman's (2000) Tailored Design Method of survey development and the use of power analysis to determine minimum sample size; both approaches were utilized in this study.

Ethical Considerations

Appropriate precautions were taken and procedures followed to provide for ethical protection of study participants. Appropriate IRB approval was obtained before any data collection was performed. Adherence to the Belmont Principles of respect for persons, beneficence, and justice was continually ensured. Because data collection was performed through Internet survey with participants solicited by e-mail invitation, additional precautions were taken to ensure participant confidentiality and data protection.

The Belmont Principles

In 1979, the U.S. Department of Health, Education, and Welfare published guidelines for protecting human subjects in biomedical and behavioral research (Ryan, et al., 1979). Commonly referred to as the Belmont Principles, the guidelines included maintaining respect for persons, treating persons with beneficence, and ensuring that the benefits of research are distributed justly. In the context of behavioral research, respect for persons requires allowing research participants to make informed, autonomous decisions about the choice to participate in research, and whether to continue participating at any stage of the study. In addition, protection must be provided for any persons whose autonomy is limited through circumstances or disability. The informed consent process developed for this study ensured potential participants were fully informed about the nature of the research, any risk to which they might be exposed, and options available for revoking their consent at any time. No participants with limited autonomy were included in the sampling frame.

Beneficence requires that research participants be treated ethically. Specifically, behavioral researchers are required to do no harm, to minimize the possibility of harm, and to maximize the possible benefits of research (Ryan, et al., 1979). Appropriate research design principles must be applied in order to achieve the highest possible benefit-to-risk ratio. In the current study, participants were exposed to no more direct risk than is typically encountered during any activity performed on the Internet. In addition, appropriate measures were taken to ensure privacy and data security.

Justice requires participants be selected fairly, and benefits and burdens of research be distributed equitably (Ryan, et al., 1979). Participant selection must not be biased intentionally to either favor or burden any particular group. In addition, the benefits and outcomes of research must be made available to all groups on a non-discriminatory basis. The current study used a random sample of a study population selected for its representativeness of the target population. After publication, outcomes of the study will be made available to all members of the professional organization which provided access to the participants.

Ethical Issues of E-mail and Internet Surveys

Use of the Internet for survey research is a widely-accepted practice, particularly in the fields of information technology and project management (Dillman, 2000; Pinsonneault & Kraemer, 1993; Sivo, et al., 2006). However, Internet and e-mail use in participant access and data gathering involves ethical issues not inherent to as great an extent in other research methods. In particular, Internet researchers must take precautions to ensure adult status and protect the privacy of survey participants.

For the current study, the sample population and sampling frame consisted of adult and university student members of the PMI IS CoP, a professional organization focused on IT project management. Membership in PMI is offered in three types: student, practitioner, and retiree. Student membership is available only to those enrolled in a degree-granting institution with U.S. accreditation or global equivalent (Project Management Institute, 2011). Since this reduces the likelihood but does not conclusively prevent students younger than 18 from joining, participants were asked to confirm in the informed consent agreement that they were 18 years of age or older.

Internet research also imposes additional requirements on protecting the privacy of participants. In the current study, no identifying information was gathered. While Internet survey hosting platforms typically include the capability of capturing the IP address of the computer used to complete the survey, SurveyMonkey allows creation and administration of surveys without IP address collection (SurveyMonkey, 2010a), an option which was utilized for the current study.

Internet survey data must be protected from access by unauthorized persons. SurveyMonkey uses password protection and validation to control access to collected survey data, as well as Secured Sockets Layer (SSL) technology for server authentication and data encryption (SurveyMonkey, 2010b). In addition, survey data was downloaded in an encrypted file and then deleted from the SurveyMonkey site once the data collection process was completed.

E-mail has become a commonly accepted method of inviting participation in Internet surveys. E-mail itself is not considered a secure communication medium; therefore it is not appropriate for sending or receiving actual survey documents. Its use, however, to send links to Internet surveys is a generally accepted practice in Internet research (Dillman, 2000; Sivo, et al., 2006).

Informed Consent and Participant Protection

Participant consent for survey completion and study participation was obtained through a positive response to an informed consent statement displayed in the survey instrument. The informed consent statement described the intent and purpose of the research being performed, and asked the participant to consent to the statement that the results of the survey would be described in a doctoral dissertation and may be included in future publications written by the researcher.

Internet research presents special requirements for informed consent. Because there is typically no direct personal contact between researchers and participants in Internet survey research, the informed consent process is complicated by several factors including confirming understanding, documenting consent, explaining risk, verifying adult status, and allowing withdrawal from the study. Researchers must take precautions to ensure participant understanding of the purpose of the study, the participant selection criteria, the effort and commitment expected, and the study risk by providing a written explanation at the beginning of the research survey.

Requirements for documenting consent in research are designed to ensure participants have received adequate information to allow them to choose whether to participate in a research study, and then documenting that they have agreed to participate. When there is personal contact between the researcher and participants, this documentation typically takes the form of a signed consent agreement. In the case of Internet survey research, consent is often obtained by asking the participant to read an informed consent agreement and click on a link to confirm agreement. This process typically does not produce a signed document. However, when participation in the study entails minimal risk to participants and there are no additional procedures or participant involvement for which additional consent would be needed, the requirement for documented consent can be waived. In addition, when a signed consent document is the only source of participant identification information linking a participant to specific survey responses, a consent document can actually increase the risk to participant privacy. Under these conditions, a researcher may apply for waiver of documented consent. In the current study, such a waiver was requested and granted.

Internet survey research makes confirming adult status more difficult since researchers cannot ask to see identification information or screen for obviously underage participants. In the current study, the professional group from which the sampling frame was derived imposes a minimum membership requirement of student status at an accredited university. Since this reduces the likelihood but does not conclusively prevent students younger than 18 from joining, participants were asked to confirm in the informed consent agreement that they were 18 years of age or older.

As with other forms of research, participants must be offered the opportunity to withdraw from a research study. The informed consent agreement for the current study explained the participant's right to withdraw at any time during the survey. Each page of the Internet survey also had a link that permitted exiting the survey without submitting the survey response.

In addition, participant protection was provided by ensuring standards and procedures for confidentiality were described including the researcher's commitment not to disclose or refer to the name or other identifying information of any study participant in any written or verbal communication. Data confidentiality retention policies include electronic archival and secure storage in the privacy of the researcher's office for a minimum of seven years.

Participant Risk

Participants were exposed to minimal risk. The greatest source of risk to most participants in behavioral and sociological research is usually unintended violations of privacy. In the current study, no information was gathered that identifies either the participant or the IP address of the computer from which the survey was completed. In addition, all data transmission and storage utilized password protection and validation to control access to survey data, as well as Secured Sockets Layer (SSL) technology for server authentication and data encryption. Once the data collection was completed, the survey data was downloaded from the survey site and archived on secured servers at the researcher's office. The online survey data was deleted.

Participant Benefits

Benefits of participation may include additional personal insight into factors contributing to IT project complexity and IT project complication and their influence on IT project success. Survey participants and all other PMI IS CoP members will be provided with access to an abbreviated copy of the published study results if they so request directly from PMI IS CoP. No other compensation or inducements, direct or indirect, were offered for participating in the study.

A recent revision of the PMI certification renewal process allowed certified Project Management Professionals to submit a request for professional development unit (PDU) credit toward recertification for participating in research studies (Project Management Institute, 2010), however, this was managed separately by PMI and was not a specific inducement for participation in any particular survey.

Personal Bias and Conflict of Interest

Potential personal or professional bias or conflict of interest in a research study must be disclosed. As a project management practitioner and educator, the researcher is a member of the group surveyed, PMI IS CoP, and the group utilized for survey pilot testing, the LinkedIn PMI-ISSIG professional networking group. No financial consideration, past, present, or future is involved in the relationships, nor is any professional status or standing subject to influence as a result of the study or its potential findings. Had any other form of personal or professional bias or conflict of interest be identified during the course of the study, appropriate disclosure would have been made to the IRB committee and to PMI IS CoP research coordinators.

CHAPTER 4. RESULTS

In this chapter, the results of the study are presented, beginning with a description of the sample. Descriptive statistics are then provided for organizational and demographical characteristics of survey participants and responses to scalar survey questions used to measure the study constructs. Results are then briefly summarized prior to a detailed description of the data analysis, results, and conclusions.

Description of the Population and Sample

In this section, a description is provided of the sample, then demographic, organizational, and project characteristics are summarized. A total of $N = 235$ fully qualified survey responses were received during the data collection period. No participants withdrew during the study. Although qualified participants were limited to U.S.-based members of the PMI IS CoP who had not participated in the pilot study, additional responses were received from PMI IS CoP members with other primary work locations, as well as from respondents who were included in the e-mail list used to solicit participation but were not PMI IS CoP members. These responses were downloaded and archived using appropriate data security procedures but were not used in the data analysis.

Sample

A priori power analysis to determine sample size for bivariate normal correlation with alpha α error probability = .05, power (1-β error probability) = .95, and medium effect size correlation $\rho = .30$ indicated a minimum sample size of $n = 115$. Post hoc power analysis for bivariate normal correlation with alpha α error probability = .05, correlation $\rho = .30$, and sample size of $N = 235$ indicated sample power (1-β error probability) = .9989. In order to evaluate the reliability of nonparametric correlation testing, post hoc power analysis for biserial rank order non-normal correlation was also performed with alpha α error probability = .05, correlation ρ = .30, and sample size of N = 235, and indicated sample power (1-β error probability) = .9992. For both types of correlation testing, the actual sample size of $N = 235$ provided statistical power > .99. This was greater than the proposed sample power of .95 used to determine the minimum sample size, indicating that the sample had sufficient statistical power for correlation analysis (Kraemer & Thiemann, 1987; Murphy & Myors, 2004).

Organizational and Demographical Characteristics

Using statistical functions of SPSS®, descriptive statistics were derived for organizational and demographic characteristics, and for individual factors and elements of ITPCx, ITPCn, and ITPS. Categories for industry sector, project type, number of employees, title, role, and annual budget or revenue were adapted from White and Fortune (2002) and the Standish Group (1994). Descriptive statistics are summarized in Tables D1 through D30 in Appendix D and discussed in the following sections.

All $N = 235$ qualified survey participants were PMI IS CoP members whose primary work location was in the U.S. and who had not participated in the pilot study. Participants represented more than 20 industries and organizations ranging in size from fewer than 10 to more than 10,000 employees. Annual revenue or budget ranged from less than \$10 million U.S. to more than \$5 billion U.S. The most common titles of survey participants were Project Manager and Program Manager; the most common project roles of survey participants were project manager, program manager, and project team member. In addition, 76% of the project managers held the PMP certification.

Industries most frequently represented by participants (see Table D1) were finance, insurance, and banking (*n* = 51, 21.70%), information technology (*n* = 48, 20.43%) and healthcare (*n* = 27, 11.49%), followed by an open-ended response of other (*n* = 25, 10.64%) for which the most commonly entered responses included pharmaceuticals, media, and government.

Organization size displayed wide variation and bimodality (see Figure 15), with the most common response of 1,000 or more employees (*n* = 120, 51.1%) followed by 10-99 employees (*n* = 49, 20.9%). A similar bimodal pattern was observed in participant responses for annual revenue or operating budget (see Figure 16). The most frequent response, more than $1 billion (*n* = 85, 36.2%) was followed by less than $100 million (*n* = 48, 20.4%).

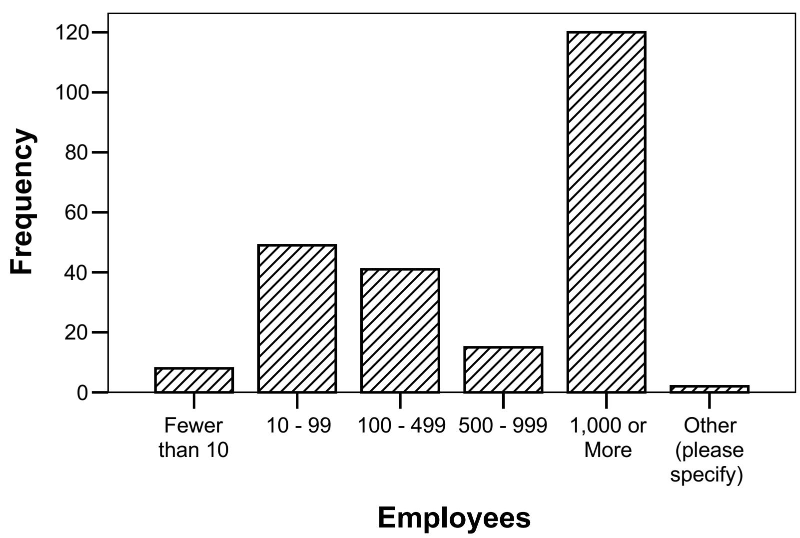


Figure 15. Employee count frequency distribution.

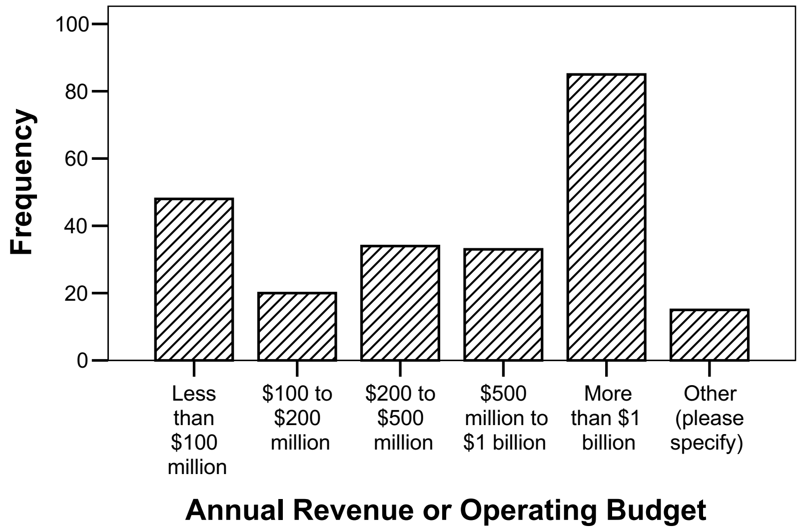


Figure 16. Annual revenue or operating budget frequency distribution.

The most common project type cited by participants (see Table D2) was information technology (*n* = 92, 39.15%), followed by software development (*n* = 77, 32.77%) and application package implementation (*n* = 26, 11.06%). The most commonly reported participant job titles (see Table D3) were Project Manager (*n* = 109, 46.38%) and Program Manager (*n* = 41, 17.45%). Similarly, the most commonly reported project roles (see Table D4) were project manager (*n* = 130, 55.32%), program manager (*n* = 59, 25.11%), and project team member (*n* = 17, 7.23%). A majority of survey participants (*n* = 178, 75.74%) reported that they or the primary project manager held the Project Management Professional (PMP) certification (see Table D5).

Descriptive statistics were also produced for project characteristics as reported for individual factors and elements of IT project complexity, IT project complication, and IT project success. In the following sections, a summary of these survey responses is provided.

IT Project Complexity

To assess the degree of IT project complexity, participants were asked to respond to a total of 26 survey questions representing 13 dimensions or elements of ITPCx. Each survey question used an ordinal Likert-type scale with five responses ranging from disagree strongly to agree strongly, or from smallest to largest on scales measuring numerical dimensions. Tables D6 through D18 summarize the response distributions and summary statistics for the elements of ITPCx and corresponding factors.

The survey contained a single question intended to assess the clarity of the project objectives at the time of project initiation (see Table D6). A majority of the participants indicated they agreed (44.26%) or agreed strongly (28.52%) that the project objectives were clear. However, the distribution indicated some bimodality in the responses, with two peaks in the corresponding histogram (see Figure 17), indicating the possibility of distinct groups represented in the data. The scale for ITPCx was reversed, as were several of the following scales where a higher level of agreement corresponded to a lower level of project complexity.

Two survey questions addressed the clarity of the problem or opportunity and its degree of familiarity to the project team (see Table D7). In most cases, the participants agreed (48.51%) or agreed strongly (34.04%) that the nature of the problem or opportunity was clear to the organization and the project team; however, there was a lower percentage who agreed (46.38%) or agreed strongly (27.66%) that the problem or opportunity was familiar to the organization. Scales for both factors were reversed prior to aggregation. While most participants indicated the problem or opportunity was clearly understood, some reported that their organizations had little prior experience addressing similar problems or opportunities.

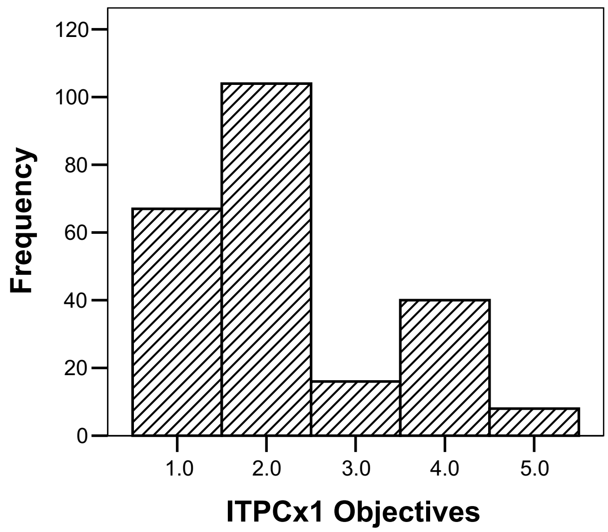


Figure 17. ITPCx1 objectives clarity scalar frequency distribution.

Also despite a high degree of clarity and familiarity with the problem or opportunity, survey participants indicated less familiarity with the actual solution implemented by the project (see Table D8). Only 31.49% of participants agreed and 22.55% agreed strongly that the project solution was familiar, while 25.53% disagreed. Similarly, 34.89% agreed and 24.26% agreed strongly that the solution was readily available in the marketplace.

Considering the experience and track record of the project team, 40.43% of participants agreed and 24.68% agreed strongly that the project team had experience with similar projects at the time the project started (see Table D9). Fewer participants indicated the team had a successful track record with such projects, with 32.77% agreeing and 20.42% agreeing strongly. The elements for experience and a track record of success with similar projects were formulated with an inverse relationship with project complexity, so the scales for team experience and track record were also reversed prior to aggregation.

Responses to the survey questions associated with the project and software development methodologies (see Table D10) indicated that more than half of the project teams used methodologies that were formal (42.55% agreed and 19.57% agreed strongly) and consistent (53.19% agreed and 23.40% agreed strongly) with other projects performed by the organization. Responses to survey questions addressing the project schedule (see Table D11) indicated that a total of 48.08% of participants agreed or agreed strongly that the project schedule was reasonable, while 41.71% disagreed or disagreed strongly. In addition, only 35.74% of participants agreed or agreed strongly that the project schedule was flexible, while 46.81% disagreed or disagreed strongly. Responses to survey questions assessing the project requirements also yielded mixed results (see Table D12). A majority of participants, 53.19%, indicated the project requirements were clearly understood, but only 19.57% indicated the requirements were stable during the life of the project, while 69.78% indicated the requirements were unstable.

Eight survey questions addressed the project environment by asking about the degree to which each environmental characteristic affected the project (see Table D13). The dimensions assessed were the project's political and strategic importance, the extent of stakeholder influence, the nature of dependencies with other projects or organizations, and any regulatory or legal influences on the project. Participants reported a wide range of project environmental influences and effects. The most frequently reported environmental characteristic with high project impact was strategic importance with 76.59% of participants indicating high or very high impact. The least common environmental impacts were regulatory with 20.00% high or very impact, and legal with 31.49% high or very high impact.

The typical project described by survey participants also exhibited an average to high degree of IT complexity and innovation (see Table D14). Only 6.38% of projects exhibited a low or very degree of IT complexity. Participants indicated that 48.09% of projects included high or very high levels of technological change (see Table D15). Similarly, 48.52% of the projects represented implemented a high or very high degree of change in the organization's business processes (see Table D16). The typical project, however, impacted an average to low extent of the entire organizational scope.

The number of separate organizations involved in the projects represented showed a bimodal distribution (see Table D17) with one peak at 3-5 organizations (31.49%) and another peak at more than 7 organizations (26.38%). The histogram in Figure 18 displays these two peaks graphically.

The number of interfaces with other systems also displayed a bimodal distribution (see Table D18) with separate peaks at 3-5 (32.77%) and more than 7 (26.38%). The results for number of organizations and interfaces indicate there may be more than one group of project sizes or types represented in the survey data.

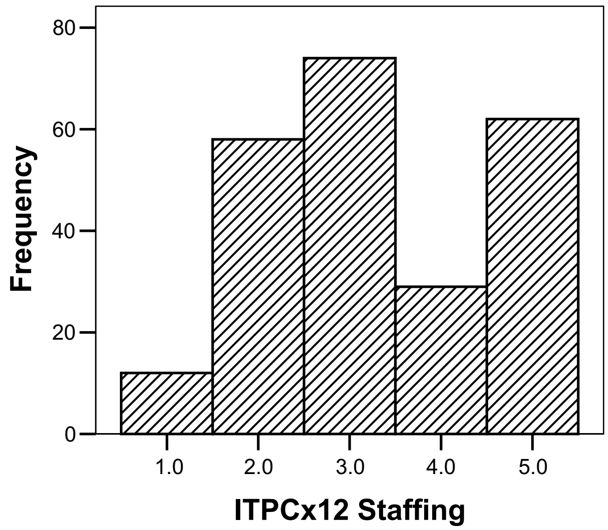


Figure 18. ITPCx12 staffing organizations scalar frequency distribution.

IT Project Complication

To measure IT project complication, participants were asked to respond to 14 survey questions representing 9 elements of ITPCn. Each survey question used an ordinal Likert-type scale with five responses ranging from disagree strongly to agree strongly, or from smallest to largest on scales measuring numerical dimensions. Tables D19 through D27 summarize the response distributions and summary statistics for each of the elements of ITPCn and any corresponding factors.

Survey participants indicated high levels of agreement with two survey questions addressing the experience and competence of the project leadership (see Table D19). A large majority of 74.04% stated the project leader had relevant experience with similar projects, and 82.55% considered the project leader to be competent. Responses to the survey question addressing project duration (see Table D20) revealed a broad distribution with 33.62% indicating the project had an originally planned duration of less than 3 months or 3-6 months, while 22.98% indicated the project had a planned duration of more than a year. Project team size also displayed a broad distribution of responses (see Table D21) with bimodality (see Figure 19). Nearly equal proportions of participants indicated team sizes of 5-10 members, 36.17%, and more than 15 members, 33.19%.

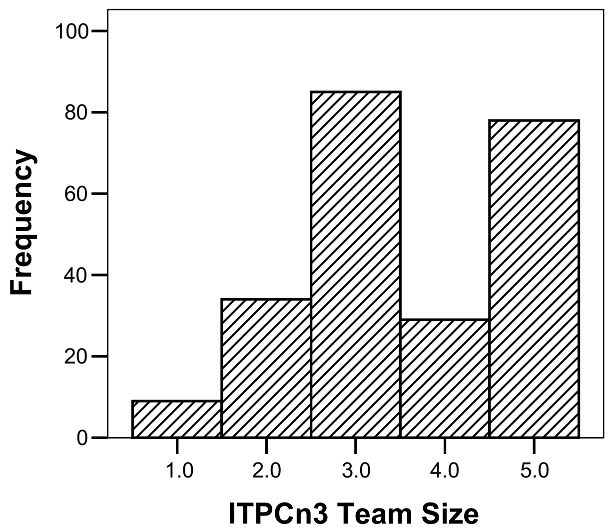


Figure 19. ITPCn3 team size scalar frequency distribution.

The planned project cost or budget (see Table D22) also displayed a large degree of bimodality (see Figure 20). A large proportion of projects (41.71%) had original planned cost less than $500,000 US, but 32.77% had original planned cost greater than $1,000,000 US.

Two survey questions addressed the project scope, differentiating between the degree of flexibility in the originally planned scope and the degree of technology content. Survey responses indicated a typical project (42.44%) was considered average in its degree of scope flexibility (see Table D23), and that technology content made up between 40% and 80% (69.78%) of the project scope (see Table D24).

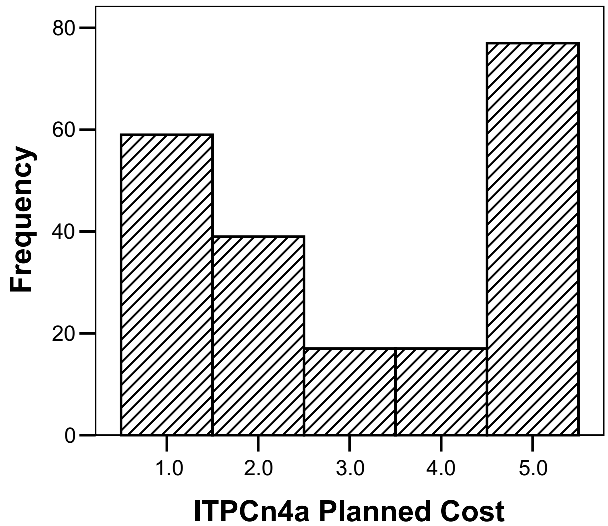


Figure 20. ITPCn4a planned cost scalar frequency distribution.

Two survey questions also addressed the degree of perceived support for the project (see Table D25). Executive support was found to be higher with 72.34% reporting high or very high executive support for the project, while only 47.66% reported high or very high user support. Results for the number of organizational units involved in the project displayed similar bimodality to other reported project attributes (see Figure 21). The most common response indicated more than 7 organizational units involved (37.02%) while the next most common response indicated 3-5 units involved (31.91%).

Bimodality for number of organizational units did not correspond to as great an extent with the number of contracts or contracting organizations (see Table D27). The typical number of contracts was smaller with 62.13% reporting 1 to 5 contracts or contracting organizations involved with the project. Contractor familiarity and track record was also generally favorable, with 45.10% of participants indicating either agreement or strong agreement that contract organizations were familiar to the project organization, and 47.66% indicating strong or very strong agreement that the contract organizations used had a positive track record of success on previous projects.

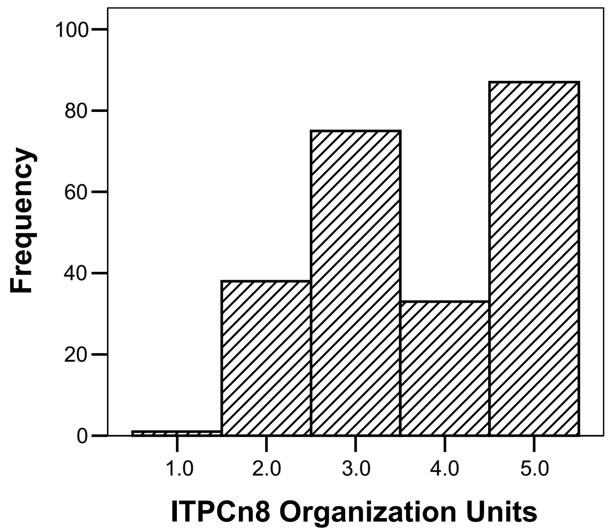


Figure 21. ITPCn8 organization units scalar frequency distribution.

IT Project Success

Similarly to ITPCx and ITPCn, survey participants were asked to respond to eight questions measuring three elements of IT project success using ordinal Likert-type scales with five responses ranging from disagree strongly to agree strongly, or from smallest to largest on scales measuring numerical dimensions. Tables D28 through D30 summarize the response distributions and summary statistics for each element and factor of ITPS.

Project completion and implementation varied with different project success criteria (see Table D28). While only 60.00% and 51.91% respectively indicated the project completed and implemented 100% or more of its original scope, 87.23% and 83.40% respectively indicated the project completed and implemented 75% or more of its original scope. Reported project success rates against the original baseline and the final baseline also differed. Only 20.00% and 27.23% of participants indicated the project was completed on or under the original schedule and budget, respectively, with 40.00% reporting the project completed 100% or more of its original scope (see Table D29). Results against the final baseline indicated a higher rate of project success with 33.62% and 35.32% of participants reporting the project was completed on or under its final schedule and budget, respectively, and 48.09% reporting the project completed 100% or more of its final scope (see Table D30). When project success metrics were broadened to consider those projects finishing less than 20% over the original and final schedules and budget, and completing 75% or more of the original and final scope, project success rates against the original baseline increased to 46.81%, 53.34%, and 68.94%, respectively. Project success rates against the final baseline displayed an even greater increase when project success criteria were broadened, with 63.83%, 63.41%, and 74.47% of projects, respectively, finishing less than 20% over the original schedule and budget and delivering more than 75% of the original scope.

Project success results measured against both the original baseline and the final baseline indicated a project failure rate of 6.0% and 17.4% respectively (see *Figure 22*). The incidence of challenged projects, or those which were completed over their initial budget and schedule, was 91.9% and 80.4% against the initial and final baselines, respectively, while the frequency of project failure remained constant with 2.1% of projects canceled or never completed.

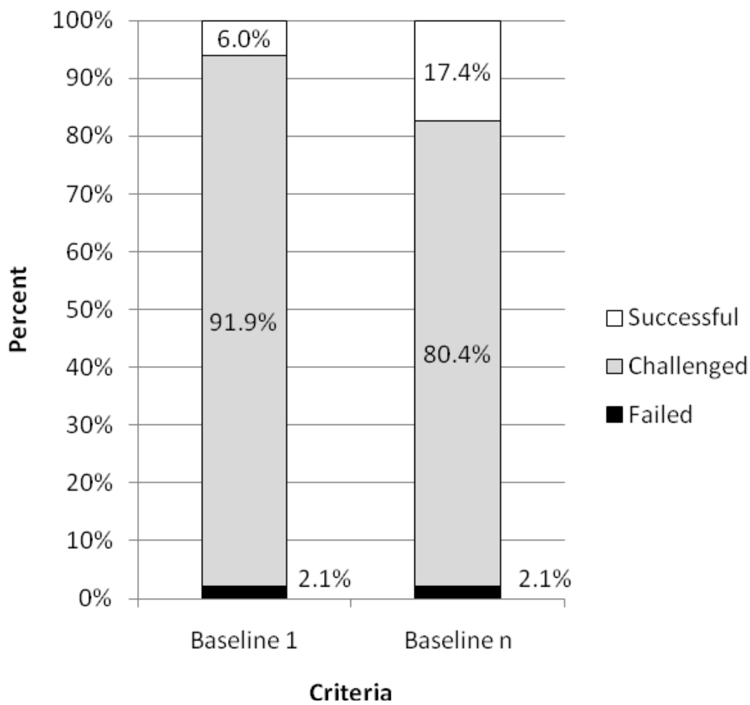


Figure 22. Percentage of projects considered successful, challenged, and failed vs. baseline 1 and baseline n.

The project success categories in this figure are based on *Chaos Summary*, 2009, by the Standish Group. Boston, MA: Author.

Project success rates by planned project duration (see Figure 23) indicated the highest percentage of projects considered successful, as measured against the final baseline, had a planned duration of 6-9 months, with 30.5% successful and 69.6% challenged. The highest rate of failure, 3.7%, was encountered on projects with planned duration greater than 12 months.

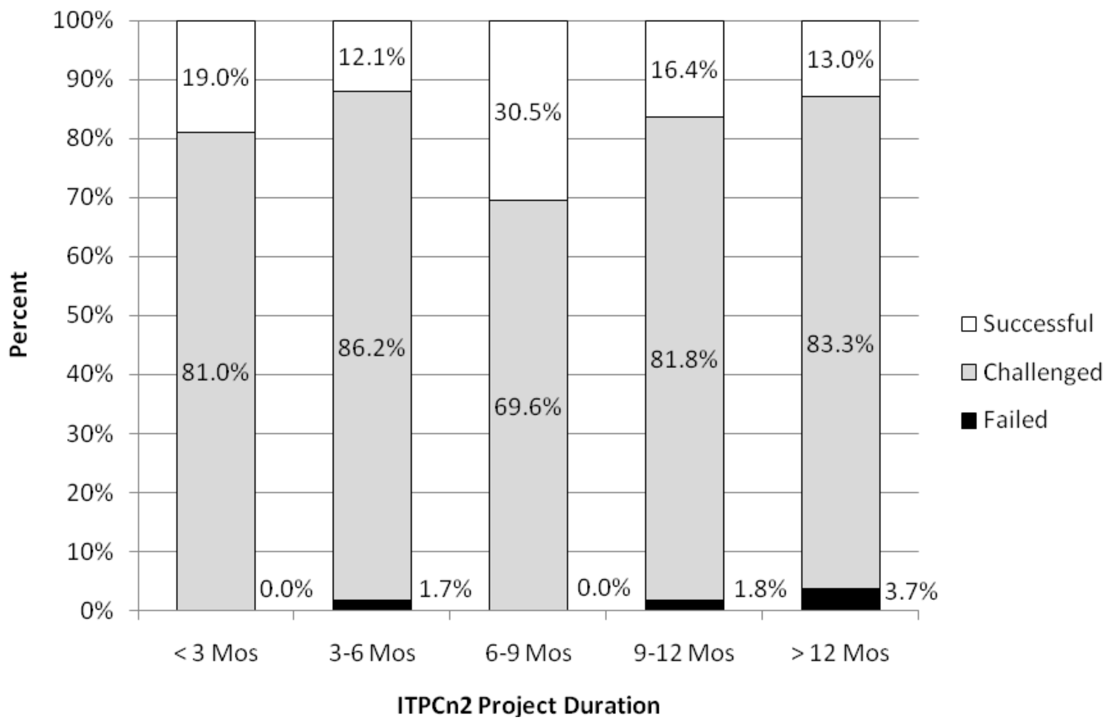


Figure 23. Project success category by project duration for baseline n.

The project success categories in this figure are based on *Chaos Summary*, 2009, by the Standish Group. Boston, MA: Author. Percentages may not add to 100% due to rounding error.

Project success rates by project team size (see Figure 24) indicated the highest success rate, 22.4%, was reported for projects with a team size of 5-10 individuals; however, this team size also had the highest reported failure rate of 3.5%. Teams smaller than 5 individuals and those larger than 15 individuals reported lower overall success rates, but lower failure rates as well.

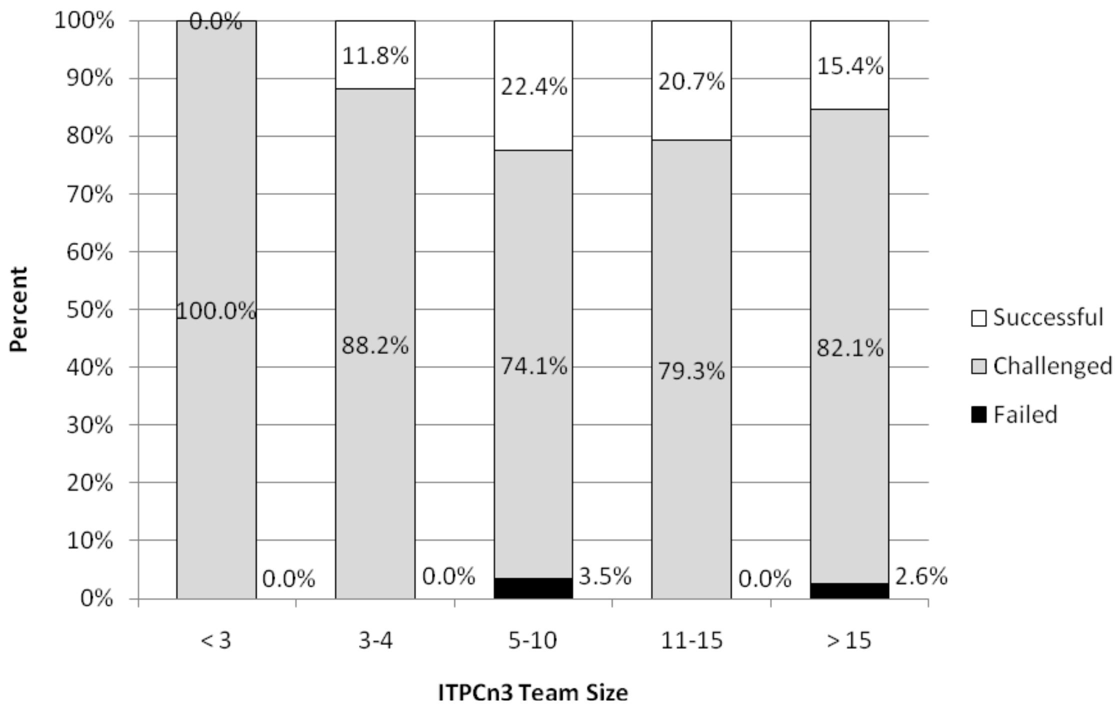


Figure 24. Project success category by project team size for baseline n.
The project success categories in this figure are based on *Chaos Summary*, 2009, by the Standish Group. Boston, MA: Author.

The highest project success rate versus project cost, 28.2%, was exhibited for projects with an initial planned cost between \$200,000 and \$500,000 U.S. (see Figure 25). The highest failure rate, 5.9%, was reported on projects with an initial planned cost between \$750,000 and \$1,000,000 U.S.

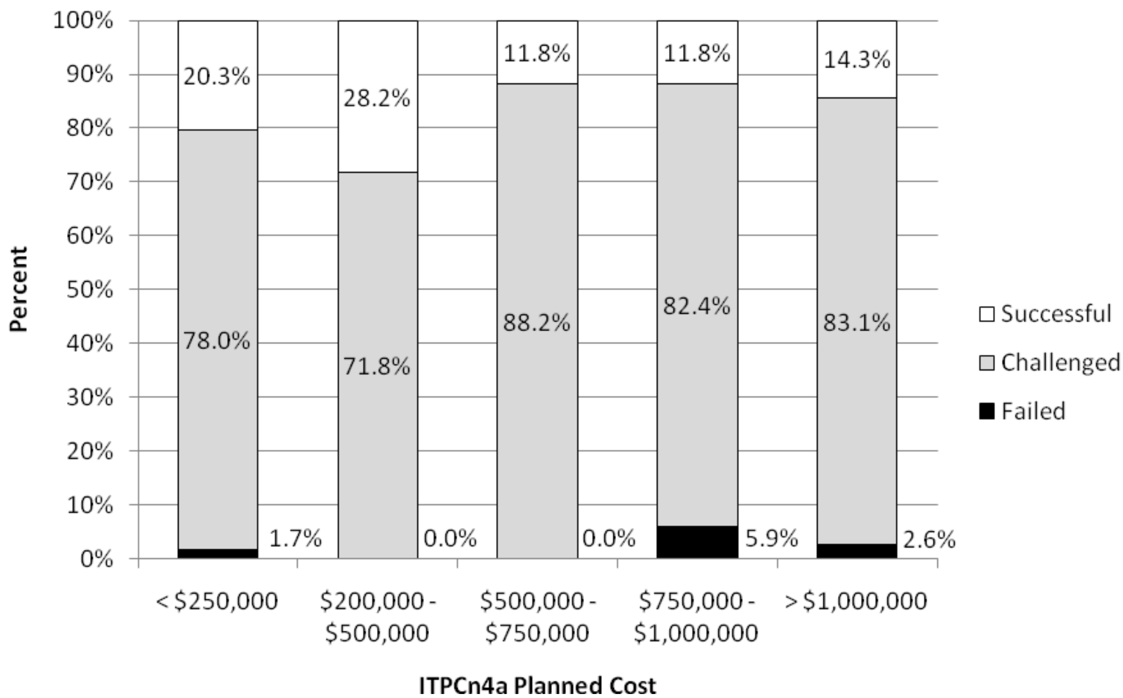


Figure 25. Project success category by project cost for baseline n.
The project success categories in this figure are based on *Chaos Summary*, 2009, by the Standish Group. Boston, MA: Author.

Summary of Results

In this section, results of data analysis are summarized briefly. Construct distribution analysis with summary statistics, histograms, and the Kolmogorov-Smirnov (Bryman & Cramer, 2005; Lehmann & Romano, 2005) and Shapiro-Wilk (Sen, 2002; Shapiro & Wilk, 1965) tests indicated ITPCx and ITPCn were normally distributed, while ITPS was not (see Table 7 and 8); therefore, a rank-based normal transform of ITPS was produced using the Rankit method (Bliss, Greenwood, & White, 1956). Chi-square analysis indicated the existence of statistically significant relationships among the constructs and the transform (see Table 11). Pearson's correlation analysis indicated statistically significant correlations between all construct and construct-transform pairs (see Table 12). Spearman's rho and Kendall's tau_b rank-order correlations were also significant for all construct and construct-transform pairs (see Table 13). Results for each research question are summarized below.

RQ1: To what extent, if any, is IT project complexity related to IT project complication?

A positive Pearson's product-moment correlation was confirmed between IT project complexity and IT project complication, $r = .530$, $r^2 = .281$, $p < .001$. Nonparametric rank order correlation was also confirmed with Kendall's tau_b $\tau = .338$, $p < .001$ and Spearman's rho $r_s = .483$, $p < .001$.

RQ2: To what extent, if any, is IT project complexity related to IT project success?

A negative Pearson's product-moment correlation was confirmed between IT project complexity and IT project success, $r = -.350$, $r^2 = .123$, $p < .001$. Nonparametric rank order correlation was also confirmed with Kendall's tau_b $\tau = -.256$, $p < .001$ and Spearman's rho $r_s = -.363$, $p < .001$.

RQ3: To what extent, if any, is IT project complication related to IT project success?

A negative Pearson's product-moment correlation was confirmed between IT project complication and IT project success, $r = -.228$, $r^2 = .052$, $p < .001$. Nonparametric rank order correlation was also confirmed with Kendall's tau_b $\tau = -.123$, $p < .01$ and Spearman's rho $r_s = -.181$, $p < .01$.

RQ4: To what extent, if any, is IT project complexity more strongly related to IT project success than is IT project complication?

Pearson's product-moment correlation coefficient for IT project complexity and IT project success, $r = -.350$, $r^2 = .123$, $p < .001$ had a greater negative value than did Pearson's product-moment correlation coefficient for IT project complication and IT project success, $r = -.228$, $r^2 = .052$, $p < .001$. Nonparametric rank order correlations for IT project complexity and IT project success, Kendall's tau_b $\tau = -.256$, $p < .001$ and Spearman's rho $r_s = -.363$, $p < .001$, also had greater negative values than did nonparametric correlations for IT project complication and IT project success, Kendall's tau_b $\tau = -.123$, $p < .01$ and Spearman's rho $r_s = -.181$, $p < .01$.

Details of Analysis and Results

In this section, a detailed description of the data processing, construct analysis, and correlation analysis is provided, and then results of data analysis are described for each research question. After data collection was completed, data processing was performed to convert the responses for some scalar questions by reversing the response scales, and to calculate aggregate scores for elements and constructs of ITPCx, ITPCn, and ITPS. Scale reversals, aggregations, and conversions were performed using spreadsheet calculations and conditional formulas directly on data downloaded from the SurveyMonkey survey hosting website.

Data Processing

Scale reversal was used for some survey questions to reduce the likelihood that negatively worded questions would have an influence on responses or that participants would be confused by changes in the response sequence (Dillman, 2000; Sheskin, 2004).

All scalar survey question responses followed an ascending pattern from left to right, even if a negative or lower response corresponded to a higher value for the factor being tested (Friedman, Herskovitz, & Pollack, 1994). Several response sets required scale reversal, including those for ITPCx1, all factors of ITPCx2 through ITPCx7, ITPCn1a and ITPCn1b, ITPCn4b, ITPCn5, ITPCn7a and ITPCn7b, ITPCn9b, and ITPCn9c. Since response scores ranged from 1 to 5, scale reversal was performed by subtracting each score's numeric value from 6 to yield a new value for the score on the reversed scale (DeCoster, 2000). In addition, the N/A or Unknown response was converted from a numeric value to a null response on all scales.

Construct aggregation was performed by summing scores on individual factors with equal weight for elements with two or more factors, then dividing by the number of factors to obtain an aggregated mean score for each multi-factor element. Element-level aggregation was then performed by summing each element score with equal weight, and dividing by the number of elements to obtain an aggregated mean score for each construct. This aggregated mean approach was used rather than score summation to reduce the possibility of elements with multiple factors receiving greater weight in the aggregate score, and to create an aggregate score measured on the same scale as the factor and element scores (Edwards, 2001). A schematic representation of the factor and element aggregation calculations for ITPCx is depicted in Figure 26.

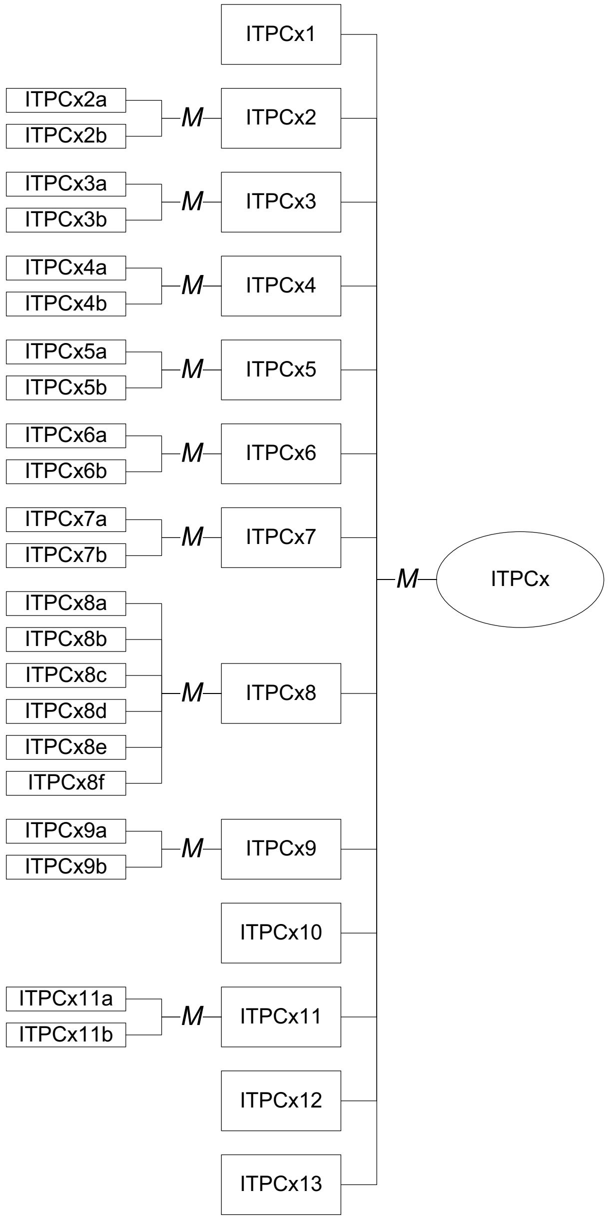


Figure 26. Construct aggregation calculations for ITPCx.

Similar aggregation calculations were performed for ITPCn (see Figure 27) and ITPS (see Figure 28). Because ITPCn had fewer elements, and fewer elements with multiple factors, factor and element aggregation was performed using the same aggregated mean approach as used for ITPCx in order to produce a construct score which was not influenced disproportionately by the number of factors associated with each element, and which was measured on the same scale as the factor and element scores.

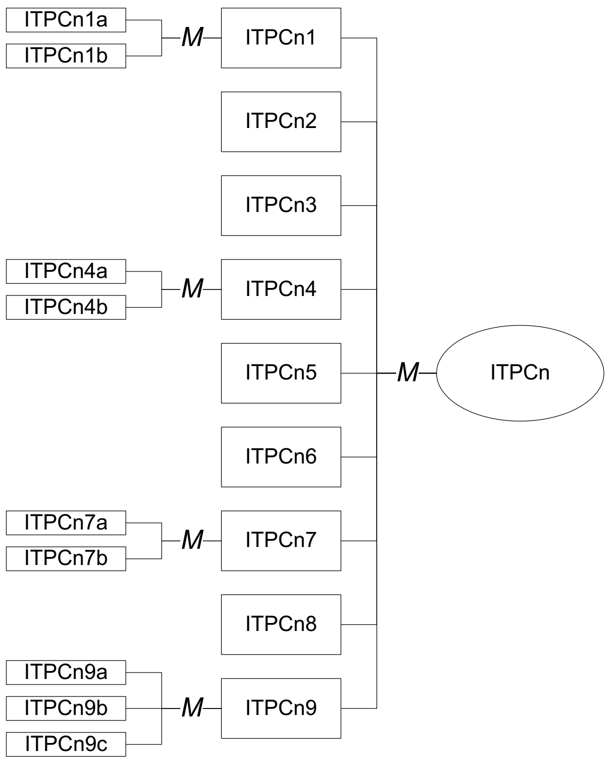


Figure 27. Construct aggregation calculations for ITPCn.

Factor and element aggregation for ITPS was also performed using the same aggregated mean approach in order to produce a construct score for ITPS measured on the same scale as ITPCx and ITPCn. While the elements of ITPS measured project success against different sets of criteria or baselines at different times during the project lifecycle, they were aggregated to produce a single score for IT project success.

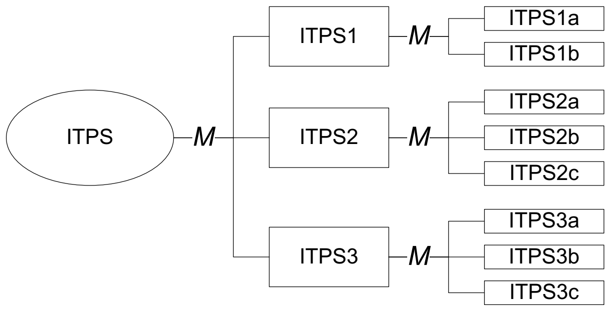


Figure 28. Construct aggregation calculations for ITPS.

After scale conversions and initial construct aggregations were completed in Excel®, all study data was imported to an SPSS® dataset and saved in the same secure location as the original survey raw data.

Construct Analysis

The processed and aggregated survey data for the individual construct, elements, and factors was first analyzed to confirm sample reliability with power analysis, and construct validity with Cronbach's alpha. Construct distributions were then evaluated for goodness of fit with the normal distribution using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Results indicated a non-normal distribution for ITPS (see Table 8), so a rank-based normal transform was derived using the Rankit method prior to correlation analysis.

Cronbach's (1951) alpha (α) was used to measure the consistency of survey questions, constructs, and construct elements, as an indicator of construct validity and internal reliability (see Table 6). The overall score α = .738 for standardized items indicated acceptable reliability for the survey instrument as a whole (M. K. Simon & Goes, 2010). Scores for standardized items for ITPCx α = .847 and ITPS α = .766 also indicated acceptable reliability. The score for standardized items of ITPCn α = .546 was lower than that for either of the other two constructs, but still within the minimum range of .5 to .6 considered sufficient for confirming reliability (Cortina, 1993; Nunnally, 1978).

Table 6

Cronbach's Alpha (α) for Standardized Items

Construct	Factors	α
ITPCx	26	.847
ITPCn	14	.546
ITPS	8	.766
Overall	48	.738

With sample reliability and construct validity confirmed, construct distributions were evaluated for goodness of fit with the normal distribution in order to assess the reliability of parametric tests for determining construct relationships.

Construct distributions were assessed with summary statistics, histograms, and statistical tests of normality including the Kolmogorov-Smirnov (Bryman & Cramer, 2005; Lehmann & Romano, 2005) and Shapiro-Wilk (Sen, 2002; Shapiro & Wilk, 1965) tests. Summary statistics (see Table 7) indicated ITPCx and ITPCn could be normally distributed, while ITPS likely was not. Summary statistics for ITPCx indicated a mean $M = 2.91$, 95% CI [2.84, 2.98], and standard deviation $SD = .544$. Skewness and kurtosis values for ITPCx indicated a slight rightward skew with moderate skewness = .150 (Hildebrand, 1986), and moderate negative kurtosis = -.300 or platykurtosis suggesting a distribution with a flatter top and thinner tails than the normal distribution (L. T.

DeCarlo, 1997). Summary statistics for ITPCn indicated a mean $M = 3.04$, 95% *CI* [2.98, 3.10], and standard deviation $SD = .480$. Tests for ITPCn also exhibited moderate right skewness = .235 and moderate platykurtosis = -.274.

Table 7

Distributions for ITPCx, ITPCn, and ITPS

		95% *CI*				
Construct	*M*	LB	UB	*SD*	Skewness	Kurtosis
ITPCx	2.91	2.84	2.98	.544	.150	-.300
ITPCn	3.04	2.98	3.10	.480	.235	-.274
ITPS	3.92	3.82	4.02	.779	-.996	.940

Summary statistics for ITPS indicated a mean $M = 3.92$, 95% *CI* [3.82, 4.02] and standard deviation $SD = .779$, corresponding to a broader distribution for ITPS than for ITPCx or ITPCn. In addition, skewness and kurtosis scores indicated ITPS was skewed significantly left with skewness = -.996, and had extensive leptokurtosis, with kurtosis = .940 indicating a narrower peak and broader tails than the normal distribution (L. T. DeCarlo, 1997), typical for a highly skewed distribution (Hopkins & Weeks, 1986).

Histograms with superimposed normal curves also provided graphical evidence of the normality of the frequency distribution for ITPCx and ITPCn, and the non-normality of the distribution for ITPS. The distribution histogram for ITPCx (see Figure 29) displayed reasonable visual fit with the normal curve, with the exception of some apparent bimodality below the mean, corresponding to the indication of platykurtosis in the summary statistics.

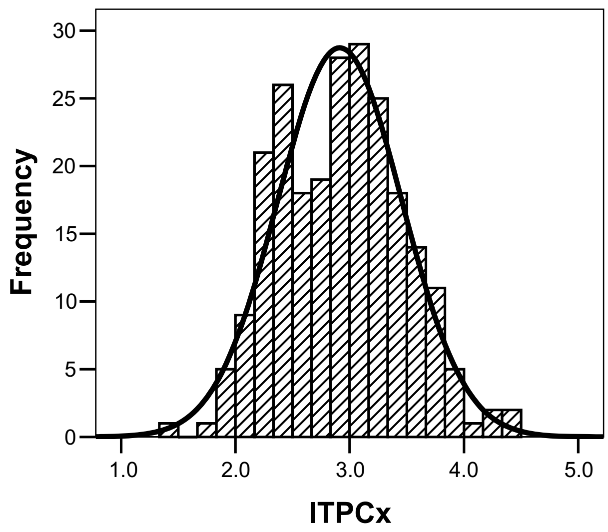


Figure 29. Distribution of ITPCx with normal curve.

The distribution histogram for ITPCn (see Figure 30) also showed reasonable visual fit with the normal curve. Apparent bimodality was less than that for ITPCx; however, there was a spike slightly above the mean and visible indication of platykurtosis as previously indicated by the summary statistics.

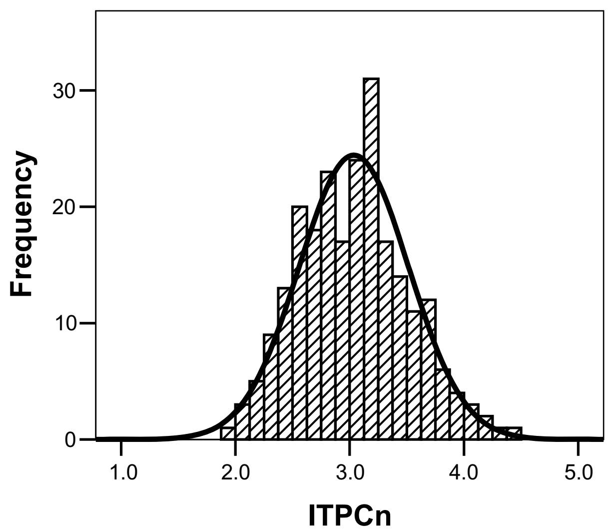


Figure 30. Distribution of ITPCn with normal curve.

The frequency distribution histogram for ITPS, however, confirmed the extent of left skewness and leptokurtosis indicated by the summary statistics (see Figure 31). The superimposed normal curve peaked near 4.0 but the apparent peak of the actual distribution was even further to the right at 4.2. In addition, there was noticeable bimodality displayed, with another local peak at 3.2.

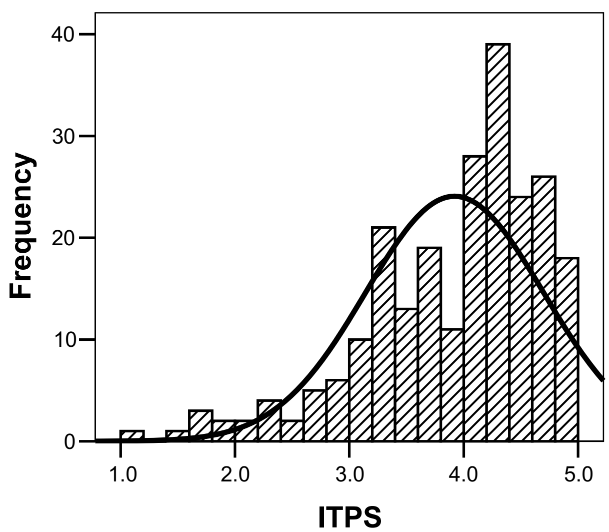


Figure 31. Distribution of ITPS with normal curve.

Statistical tests of normality including the Kolmogorov-Smirnov (K-S) test with the Lilliefors significance correction and the Shapiro-Wilk (S-W) test were also performed to compare the observed frequencies of responses for the constructs of ITPCx, ITPCn, and ITPS with the normal distribution (see Table 8). Results confirmed that the distribution of ITPCx was not significantly different from the normal distribution with a K-S value of .053, $p > .2$ and a S-W value of .991, $p = .165$. Results also confirmed that the distribution of ITPCn was not significantly different from the normal distribution with a K-S value of .039, $p > .2$ and a S-W value of .993, $p = .348$. From these results it could be concluded that the values of ITPCx and ITPCn were normally distributed (Bryman & Cramer, 2005; Lehmann & Romano, 2005; Sen, 2002; Shapiro & Wilk, 1965).

Table 8

Statistical Tests of Normality for Constructs of ITPCx, ITPCn, and ITPS

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Construct	Statistic	*df*	Significance	Statistic	*df*	Significance
ITPCx	.053	235	>.200	.991	235	.165
ITPCn	.039	235	>.200	.993	235	.348
ITPS	.115	235	.000	.931	235	.000

[a]Lilliefors significance correction.

The results of the statistical tests of normality for ITPS supported the summary statistical and graphical evidence indicating that the distribution of ITPS was significantly different from the normal distribution, with a K-S value of .115, $p < .001$, and an S-W value of .931, $p < .001$, indicating possible detrimental effects of non-normal distributions on the reliability of parametric tests of correlation such as the Pearson's product-moment (Kowalski, 1972).

In order to increase the reliability of construct correlation analysis, a number of data transformations for ITPS were investigated including log, exponential, and clustering methods. Of the initial transformations tested, only the cube transformation, ITPS^3, yielded a distribution with reasonable graphical evidence of normality (see Figure 32). However, subsequent testing of normality with the K-S and S-W tests indicated the distribution of ITPS^3 was still significantly different from the normal distribution with $p < .01$ for both tests (see Table 9).

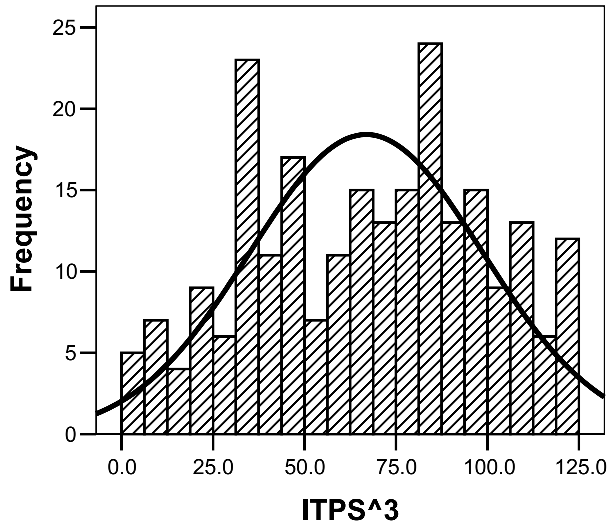


Figure 32. Distribution of ITPS^3 with normal curve.

Further investigation and comparison of rank-based normal transformations including the Van der Waerden, Blom, Rankit, and Tukey methods (Solomon, 2008; Solomon & Sawilowsky, 2009) indicated most reliable results were obtained with a normal transformation of ITPS using the Rankit method (Bliss, et al., 1956). The normal transformation, NITPS, displayed visible graphical evidence of normal distribution (see Figure 33) which was confirmed by the results of the K-S and S-W tests (see Table 9), indicating the distribution of NITPS was not significantly different from the normal distribution with $p > .200$ and $p = .165$, respectively.

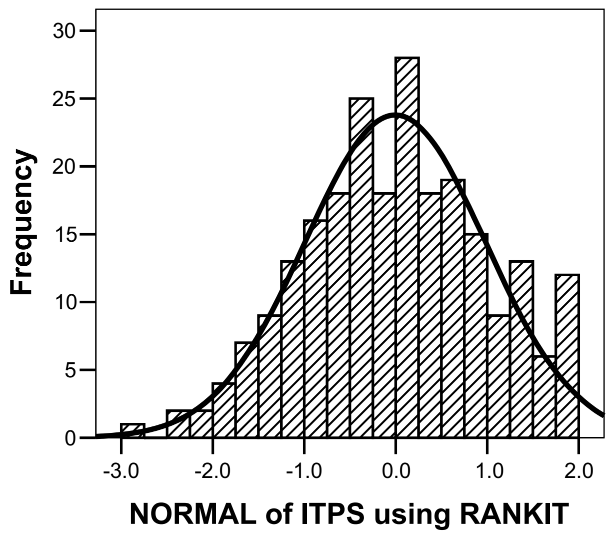


Figure 33. Distribution of NITPS with normal curve.

Table 9

Statistical Tests of Normality for Transforms of ITPS

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Transform	Statistic	*df*	Significance	Statistic	*df*	Significance
ITPS^3	.070	235	.008	.977	235	.001
NITPS	.042	235	>.200	.991	235	.165

[a]Lilliefors significance correction.

As further confirmation of the graphical evidence and statistical tests of normality, summary statistics were determined for the distributions of the transforms of ITPS (see Table 10). The cube transform ITPS^3 had minor left skewness = -.042 but extensive platykurtosis = -.852. The normal transform NITPS also had minor left skewness = -.091 but less platykurtosis = -.261, lower than that for either ITPCx or ITPCn.

Table 10

Distributions for Transforms of ITPS

Transform	*M*	95% *CI* LB	95% *CI* UB	*SD*	Skewness	Kurtosis
ITPS^3	66.87	62.78	78.96	31.82	-.042	-.852
NITPS	-.005	-.132	.121	.985	-.091	-.261

With goodness of fit against the normal distribution confirming the ordinal data could be treated as interval data for correlation analysis (Bryman & Cramer, 2005; Lehmann & Romano, 2005; Sen, 2002; Shapiro & Wilk, 1965), construct relationships were next investigated to confirm existence of statistical relationships among the constructs, then to determine the strength and statistical significance of the relationships.

Correlation Analysis

Results of construct correlation analysis indicated significant relationships for all construct pairs based on the normal approximation; however, since ITPS was not normally distributed, analysis was also performed using the NITPS transform. Chi-square results indicated the existence of statistically significant relationships among the constructs and the transform. Chi-square results are summarized in Table 11 with χ^2 (6, N = 235) = 57.846, $p < .001$ for ITPCx-ITPCn, χ^2 (12, N = 235) = 44.005, $p < .001$ for ITPCx-ITPS, χ^2 (8, N = 235) = 24.036, $p < .01$ for ITPCn-ITPS, χ^2 (15, N = 235) = 61.710, $p < .001$ for ITPCx-NITPS, and χ^2 (10, N = 235) = 40.013, $p < .001$ for ITPCn-NITPS. Chi-square results for all five construct pairs exhibited cells with expected count fewer than 5, however p values indicated the relationships were significant.

Table 11

Pearson's Chi-Square Crosstabs

Paired constructs	χ^2	*df*	*R*	*p*
ITPCx-ITPCn	57.846[a]	6	.435	.000
ITPCx-ITPS	44.005[b]	12	-.339	.000
ITPCn-ITPS	24.036[c]	8	-.177	.006
ITPCx-NITPS	61.710[d]	15	-.354	.000
ITPCn-NITPS	40.013[e]	10	-.218	.000

Note. Based on normal approximation.
[a]4 cells (33.3%) with expected count less than 5. [b]10 cells (50.0%) with expected count less than 5. [c]5 cells (33.3%) with expected count less than 5. [d]13 cells (54.2%) with expected count less than 5. [e]7 cells (38.9%) with expected count less than 5.

With the existence of statistically significant relationships confirmed, Pearson's product-moment correlation analysis was performed for all construct and construct-transform pairs, and for the interaction term ITPCxITPCn and the normal transform NITPS. Results indicated statistically significant correlations between all construct and construct-transform pairs, and between the interaction term and the normal transform (see Table 12).

Table 12

Pearson's Correlations between Paired Constructs

Paired constructs	r	r^2	p
ITPCx-ITPCn	.530	.281	.000
ITPCx-ITPS	-.356	.127	.000
ITPCn-ITPS	-.247	.061	.000
ITPCx-NITPS	-.350	.123	.000
ITPCn-NITPS	-.228	.052	.000
ITPCxITPCn-NITPS	-.185	.034	.004

Note. ITPS is not normally distributed.

All construct pairs and construct-transform pairs indicated statistically significant Pearson's product-moment correlations. The relationship between ITPCx and ITPCn was found to be the strongest (r = .530, r^2 = .281, p < .001) among all the pairs and to exhibit a large effect size (J. Cohen, 1988, 1992). Correlations between ITPCx and ITPS and between ITPCn and ITPS were evaluated but not considered reliable since ITPS was not normally distributed and therefore violated the assumptions of the Pearson's product-moment test. Correlations between ITPCx and NITPS (r = -.350, r^2 = .123, p < .001) and between ITPCn and NITPS (r = -.228, r^2 = .052, p < .001) were both negative, indicating inverse relationships of small to medium effect size (J. Cohen, 1988, 1992) between both independent variables and the dependent variable. With r^2 = .123, the ITPCx-NITPS pair had greater explanatory value than the ITPCn-NITPS pair with r^2 = .052. The correlation between the interaction term ITPCxITPCn and the normal transform NITPS was the weakest (r = -.185, r^2 = .034, p < .01), indicating that while ITPCx and ITPCn were positively related, they each had greater individual explanatory value for NITPS than did the interaction term ITPCxITPCn.

Since the distribution of ITPS was found not normal, nonparametric tests of correlation were utilized to investigate the relationships between ITPCx, ITPCn, and ITPS. Spearman's rho and Kendall's tau_b rank-order correlations were evaluated for all construct and construct-transform pairs, as well as for the interaction term and normal transform pair (see Table 13). Results indicated statistically significant rank order nonparametric correlations between all pairs, with the exception of the ITPCxITPCn and NITPS pair. The relationship between ITPCx and ITPCn was the strongest ($\tau = .338$, $p < .001$; $r_s = .483$, $p < .001$), supporting the results of the parametric correlation testing. Also consistent with the results from parametric testing, the negative nonparametric correlation between ITPCx and ITPS ($\tau = -.256$, $p < .001$; $r_s = -.363$, $p < .001$) was stronger than that between ITPCn and ITPS ($\tau = -.123$, $p < .01$; $r_s = -.363$, $p < .01$). The nonparametric correlation between ITPCxITPCn and NITPS was not statistically significant ($\tau = -.051$, $p > .2$; $r_s = -.078$, $p > .2$).

Table 13

Nonparametric Correlations between Paired Constructs

Paired constructs	Kendall's tau_b τ	Kendall's tau_b p	Spearman's rho r_s	Spearman's rho p
ITPCx-ITPCn	.338	.000	.483	.000
ITPCx-ITPS	-.256	.000	-.363	.000
ITPCn-ITPS	-.123	.006	-.181	.005
ITPCx-NITPS	-.256	.000	-.363	.000
ITPCn-NITPS	-.123	.000	-.181	.005
ITPCxITPCn-NITPS	-.051	.248	-.078	.236

Results of parametric and nonparametric correlation analysis indicated that the two independent variable constructs, ITPCx and ITPCn, were positively correlated, and that each was individually negatively correlated with ITPS. Scatter plots of ITPCx and ITPCn, ITPCx and ITPS, and ITPCn and ITPS with derived regression lines are shown in Figures 34 through 36; however, since all three graphs indicated high levels of variability or heteroscedasticity, no further regression analysis was performed. Analysis of potential outliers indicated no outliers for ITPCx, one potential outlier for ITPCn, and one potential outlier for ITPS, but review of the actual survey data justified the extreme values for the individual cases, so no attempts were made to remove outliers to produce a reduced response set.

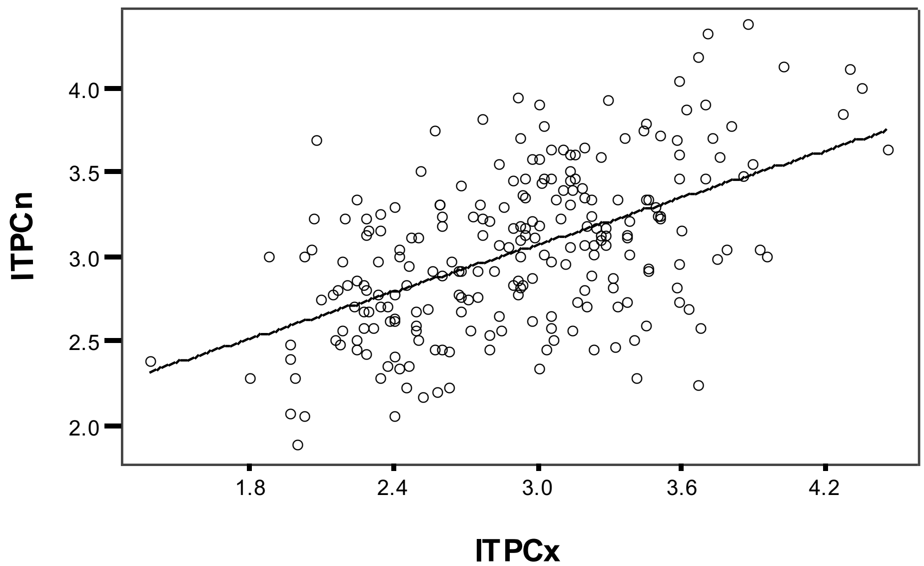


Figure 34. Scatter plot of ITPCx vs. ITPCn.

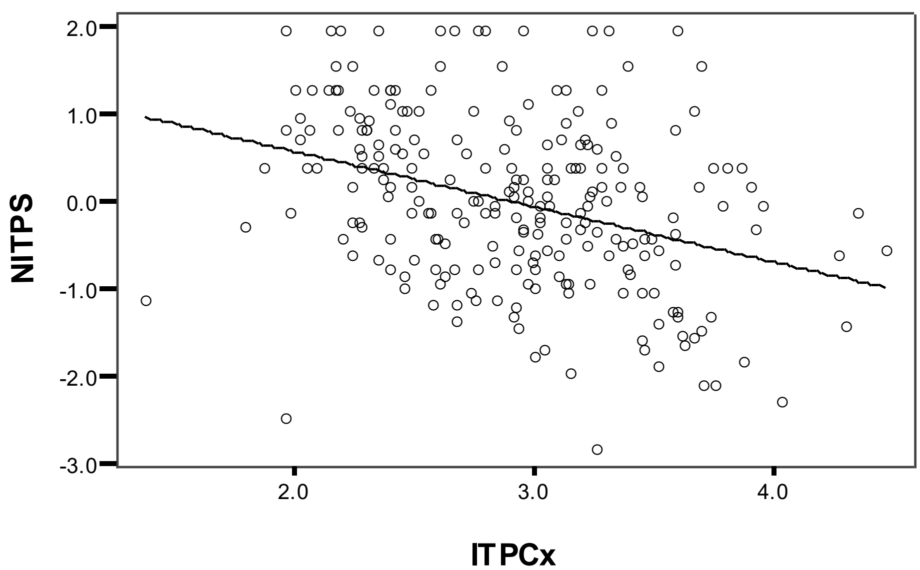


Figure 35. Scatter plot of ITPCx vs. NITPS.

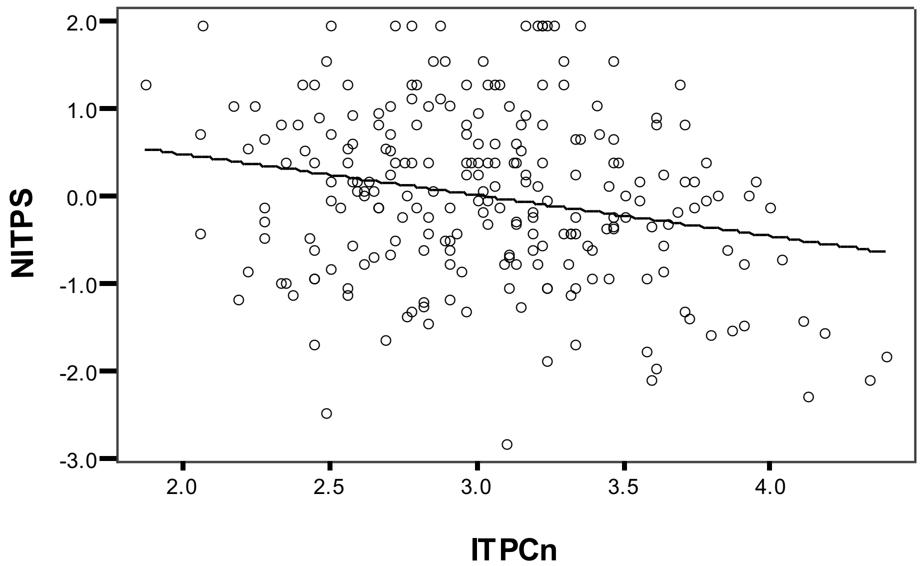


Figure 36. Scatter plot of ITPCn vs. NITPS.

Results of the correlation analysis were applied to develop a revised conceptual model (see Figure 37). In the revised model, all three relationships are depicted as statistically significant as hypothesized. The relationship between ITPCx and ITPS is shown as stronger than that between ITPCn and ITPS as hypothesized. The relationship between ITPCn and ITPS, while significant, has the lowest explanatory power and is therefore indicated as of secondary interest.

The revised conceptual model summarizes the relationships found among the study constructs. Detailed results for each research question are presented in the following sections.

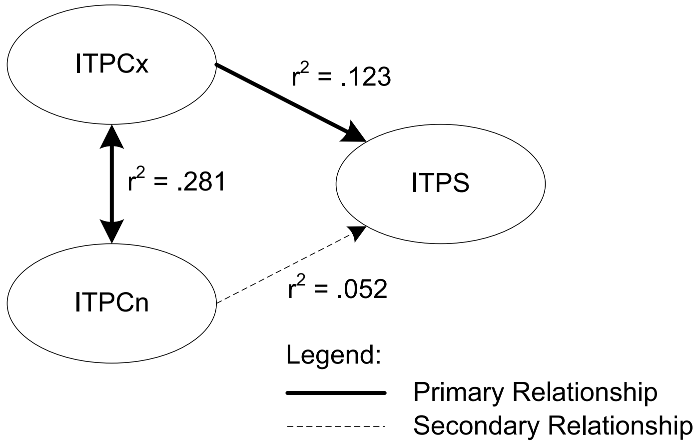


Figure 37. Revised conceptual model.

Research Question 1: ITPCx relationship with ITPCn

RQ1: To what extent, if any, is IT project complexity related to IT project complication?

$H1_0$: IT project complexity is not correlated with IT project complication

$H1_A$: IT project complexity is correlated with IT project complication

Pearson's correlation analysis confirmed a positive correlation existed between IT project complexity and IT project complication, $r = .530$, $r^2 = .281$, $p < .001$. Nonparametric rank order correlation was also confirmed with Kendall's tau_b $\tau = .338$, $p < .001$ and Spearman's rho $r_s = .483$, $p < .001$.

Finding 1: $H1_0$ rejected. IT project complexity was positively correlated with IT project complication; $p = .000$ was less than the significance level .05 for bivariate normal correlation indicated by post hoc power analysis.

Research Question 2: ITPCx relationship with ITPS

RQ2: To what extent, if any, is IT project complexity related to IT project success?

$H2_0$: IT project complexity is not correlated with IT project success

$H2_A$: IT project complexity is correlated with IT project success

Pearson's correlation analysis confirmed a negative correlation existed between IT project complexity and IT project success, $r = -.350$, $r^2 = .123$, $p < .001$. Nonparametric rank order correlation was also confirmed with Kendall's tau_b $\tau = -.256$, $p < .001$ and Spearman's rho $r_s = -.363$, $p < .001$.

Finding 2: $H2_0$ rejected. IT project complexity was negatively correlated with IT project success; $p = .000$ was less than the significance level .05 for bivariate normal correlation indicated by post hoc power analysis.

Research Question 3: ITPCn relationship with ITPS

RQ3: To what extent, if any, is IT project complication related to IT project success?

$H3_0$: IT project complication is not correlated with IT project success

$H3_A$: IT project complication is correlated with IT project success

Pearson's correlation analysis confirmed a negative correlation existed between IT project complication and IT project success, $r = -.228$, $r^2 = .052$, $p < .001$. Nonparametric rank order correlation was also confirmed with Kendall's tau_b $\tau = -.123$, $p < .01$ and Spearman's rho $r_s = -.181$, $p < .01$.

Finding 3: $H3_0$ rejected. IT project complication was negatively correlated with IT project success; $p = .000$ was less than the significance level .05 for bivariate normal correlation indicated by post hoc power analysis.

Research Question 4: ITPCx relationship with ITPS versus ITPCn relationship with ITPS

RQ4: To what extent, if any, is IT project complexity more strongly related to IT project success than is IT project complication?

$H4_0$: IT project complication has an equal or greater correlation with IT project success than does IT project complexity

$H4_A$: IT project complexity has a greater correlation with IT project success than does IT project complication

Pearson's correlation coefficient for IT project complexity and IT project success, $r = -.350$, $r^2 = .123$, $p < .001$ had a greater negative value than did Pearson's correlation coefficient for IT project complication and IT project success, $r = -.228$, $r^2 = .052$, $p < .001$. Nonparametric rank order correlations for IT project complexity and IT project success, Kendall's tau_b $\tau = -.256$, $p < .001$ and Spearman's rho $r_s = -.363$, $p < .001$ also had greater negative values than did nonparametric correlations for IT project complication and IT project success, Kendall's tau_b $\tau = -.123$, $p < .01$ and Spearman's rho $r_s = -.181$, $p < .01$.

Finding 4: $H4_0$ rejected. IT project complexity had a greater negative correlation with IT project success than did IT project complication.

Rejection of the first three null hypotheses $H1_0$ – $H3_0$ confirmed the existence of statistically significant correlations between the two independent variables ITPCx (X_1) and ITPCn (X_2), and between each independent variable and the dependent variable ITPS (Y). In addition, rejection of the fourth null hypothesis $H4_0$ confirmed the correlation between ITPCx (X_1) and ITPS (Y) was stronger than the correlation between ITPCn (X_2) and ITPS (Y).

Conclusions

Results of data analysis performed for RQ1 provided evidence that the positive correlation between IT project complexity and IT project complication ($r = .530$, $r^2 = .281$, $p < .001$) was stronger than that between either variable and IT project success. Results of the data analysis performed for RQ2, RQ3, and RQ4 provided empirical evidence that IT project complexity and IT project success were negatively correlated ($r = -.350$, $r^2 = .123$, $p < .001$) to a greater degree than were IT project complication and IT project success ($r = -.228$, $r^2 = .052$, $p < .001$). In addition, results provided evidence that the interaction term ITPCxITPCn was less strongly negatively correlated with ITPS ($r = -.185$, $r^2 = .034$, $p < .01$) than were either of the individual constructs. Implications of these findings and recommendations for practitioners and future researchers are discussed in Chapter 5.

CHAPTER 5. DISCUSSION

In this chapter, a summary of the study is presented with findings from data analysis, supporting discussion, and conclusions. In addition, recommendations are made for practitioner application of results as well as improvements to the current study and opportunities for further research.

Summary of the Results

The specific problem addressed in this study was the consistently low reported success rate of IT projects in the U.S. The widely-cited Standish Group (1994, 1999, 2001b, 2007, 2008, 2009) research has found IT project success rates ranging from 16% to 35% and IT project failure ranging from 18% to 40% over a 15-year period. Other researchers have questioned whether the Standish figures overstate the problem (El Emam & Koru, 2008; Eveleens & Verhoef, 2009; Glass, 2006b), and the survey data collected for this study indicated that a larger percentage of IT projects may be at least partially successful, especially when evaluated against their final objectives as well as against their initial objectives.

Information technology project failures and overruns are reported to impact the U.S. economy by at least $1.2 trillion a year (Sessions, 2009). Commonly cited causes of IT project failure include many factors such as lack of alignment between IT and business objectives, lack of management and user support, poor project management practices, and project team inexperience (Glass, 1998; Hass, 2009; J. Johnson, 2006); but another possible cause of IT project failure may be unrecognized and unaddressed project complexity (Benbya & McKelvey, 2006).

The objectives of this study were to help clarify the distinction between project complexity and project complication, to identify project characteristics that may contribute to IT project complexity and IT project complication, and to assess the relationships between IT project complexity, IT project complication, and IT project success. To achieve these objectives, an extensive literature review was performed, a conceptual model was synthesized, a survey instrument was developed to measure attributes of these constructs, and correlation analysis was performed to assess the relationships among the constructs.

The literature reviewed for this study focused on the three major themes of project management theory and project complexity, information technology project complexity, and information technology project success. The predominant body of project management theory is based on the rational systems view (Fayol, 1949/1919; March & Simon, 1958; Taylor, 1919); however, projects are temporary organizations which can be characterized as rational, natural, open, or complex adaptive systems (Boulding, 1956; Buckley, 1968; Churchman, 1968; Von Bertalanffy, 1972).

This study applied a complex adaptive systems view to project characteristics related to information technology project success. Complexity is an inherent characteristic of information technology (Hassan & Holt, 2003; McDonald, 2001) that limits advances in IT project management effectiveness (Brooks, 1995). Cilliers (1998) distinguished between complexity and complication. Hass (2007a, 2007b, 2009) developed a model of project complexity that included project characteristics related to both complexity and complication. In this study, a distinction was made between IT project complexity and IT project complication. To assess IT project success, this study utilized success criteria developed by the Standish Group (1994, 1999, 2009) based on the triple constraint dimensions of schedule, budget, and scope, supplemented with project completion and implementation. A quantitative survey instrument was developed for the study to measure project characteristics associated with project complexity, project complication, and project success. Results of data analysis indicated a statistically significant relationship between IT project complexity and IT project success that was stronger than the relationship between IT project complication and IT project success. In the following section, study limitations are discussed briefly and then the study findings related to the research questions are summarized and discussed.

Discussion of the Results

Generalizability of the study results may have been limited by a number of factors including the nature of the sample, the structure of some of the survey questions, the immaturity of the variable constructs, the discovery of a non-normal distribution for IT project success, and the low strength of the correlations between IT project complexity and IT project complication, respectively, and IT project success. These issues are addressed in more detail in the limitations section later in this chapter. Study results did confirm, however, a positive correlation between IT project complexity and IT project complication, a negative correlation between IT project complexity and IT project success, and a negative correlation between IT project complication and IT project success. In the following sections, the study results are summarized and discussed sequentially in the context of each of the research questions.

Research Question 1: ITPCx relationship with ITPCn

RQ1: To what extent, if any, is IT project complexity related to IT project complication?

$H1_0$: IT project complexity is not correlated with IT project complication

$H1_A$: IT project complexity is correlated with IT project complication

Finding 1: $H1_0$ rejected. IT project complexity was positively correlated with IT project complication.

Results of data analysis for RQ1 indicated the two independent variables, IT project complexity and IT project complication, had a positive Pearson's product-moment correlation, $r = .530$, $r^2 = .281$, $p < .001$. The explanatory power of the relationship $r^2 = .281$ was greater than that for the relationships between either independent variable and the dependent variable, IT project success. Nonparametric correlations between IT project complexity and IT project complication $\tau = .338$, $p < .001$ and $r_s = .483$, $p < .001$ were also greater than those found between either independent variable and IT project success.

While these results confirmed the original hypothesis of a positive correlation between the two independent variables, the degree of variability in the relationship and the strength of the relationship compared to the relationships between the independent variables and the dependent variable were noteworthy. In the original conceptual model, a distinction was made between IT project complexity and IT project complication. The variance or heteroscedasticity of the relationship around the positively sloped regression line in the scatter plot of ITPCx and ITPCn (see Figure 34) indicated that IT project complexity and IT project complication were related but distinct sets of IT project characteristics. These results indicated that IT projects can and do present differing degrees of complexity and complication. Implications for practitioners include the importance of recognizing the difference between the two sets of project characteristics and the understanding that they are not necessarily present in equal proportions on a given project. This understanding can lead to more effective selection of project management methods and project success criteria for projects with differing degrees of complexity and complication.

The unexpected result of a stronger correlation between IT project complexity and IT project complication than between either IT project complexity or IT project complication and IT project success had a number of possible explanations. The distinction between the two sets of project characteristics applied in the conceptual model had not been previously evaluated or empirically tested. While the composition of the study constructs, elements, and factors was based on an extensive review of prior studies, it is possible that factors related to IT project complexity and IT project complication were comingled, resulting in a stronger correlation between the constructs than would have been observed if the factors had been aggregated differently. Factor analysis and structural equation modeling were outside the scope of this study; however, the application of these methods may have revealed the existence of weak or negative intra-scale correlations among the factors and elements of IT project complexity and IT project success. It is possible that a reduced or restructured set of factors and elements for each construct may have yielded stronger correlations. It is also possible that other moderating or confounding variables were present that resulted in weaker correlations between ITPCx and ITPCn, respectively, and ITPS than expected. Implications for both practitioners and researchers include the importance of further research into factors contributing to IT project complexity and IT project complication as distinct sets of project characteristics, leading to the development of more effective models for analyzing IT projects and selecting project management methods and approaches that lead to greater likelihood of IT project success.

Research Question 2: ITPCx relationship with ITPS

RQ2: To what extent, if any, is IT project complexity related to IT project success?

$H2_0$: IT project complexity is not correlated with IT project success

$H2_A$: IT project complexity is correlated with IT project success

Finding 2: $H2_0$ rejected. IT project complexity was negatively correlated with IT project success.

Results of data analysis for RQ2 indicated the constructs for IT project complexity and IT project success had a negative Pearson's product-moment correlation, $r = -.350$, $r^2 = .123$, $p < .001$. The explanatory power of the relationship $r^2 = .123$ was less than that for the relationship between IT project complexity and IT project complication, $r^2 = .281$, but greater than that for IT project complication and IT project success, $r^2 = .052$. Nonparametric correlations between IT project complexity and IT project success $\tau = -.256$, $p < .001$ and $r_s = -.363$, $p < .001$ were also more strongly negative than those found between IT project complication and IT project success.

These results confirmed the original hypothesis of a negative correlation between IT project complexity and IT project success; however, the effect size was weaker than expected. Possible explanations are similar to those discussed for RQ1. Further analysis of intra-scale correlations through factor analysis and structural equation modeling may have resulted in a reduced set of construct factors and elements for IT project complexity and a stronger negative correlation with IT project success. Implications of these results for practitioners and researchers include the urgency of further study of these relationships, leading to practical application of project screening and assessment tools for better diagnosis of IT project complexity, as well as more extensive investigation into the effects of IT project complexity on IT project success and any moderating or confounding variables.

Research Question 3: ITPCn relationship with ITPS

RQ3: To what extent, if any, is IT project complication related to IT project success?

$H3_0$: IT project complication is not correlated with IT project success

$H3_A$: IT project complication is correlated with IT project success

Finding 3: $H3_0$ rejected. IT project complication was negatively correlated with IT project success.

Results of data analysis for RQ3 indicated IT project complication and IT project success had a negative Pearson's product-moment correlation, $r = -.228$, $r^2 = .052$, $p < .001$. The explanatory power of the relationship $r^2 = .052$ was the weakest among the relationships between the study constructs. Nonparametric correlations between IT project complication and IT project success $\tau = -.123$, $p < .01$ and $r_s = -.181$, $p < .01$ were also the weakest found between study constructs.

These results confirmed the original hypothesis of a negative correlation between IT project complication and IT project success. The effect size, $r^2 = .052$, $p < .001$, was statistically significant but weak, indicating a weak relationship between IT project complication and IT project success. Possible causes of the weak effect size are similar to those discussed for RQ1 and RQ2, but it is possible that the underlying relationship itself is weak. Factor analysis and structural equation modeling may have resulted in a reduced set of factors and elements for IT project complication and a stronger negative correlation with IT project success. Further investigation of the effects of IT project complication and other moderating or confounding variables on IT project success appears to be warranted.

Research Question 4: ITPCx relationship with ITPS versus ITPCn relationship with ITPS

RQ4: To what extent, if any, is IT project complexity more strongly related to IT project success than is IT project complication?

$H4_0$: IT project complication has an equal or greater correlation with IT project success than does IT project complexity

$H4_A$: IT project complexity has a greater correlation with IT project success than does IT project complication

Finding 4: $H4_0$ rejected, IT project complexity had a greater negative correlation with IT project success than did IT project complication.

Results of data analysis for RQ4 indicated IT project complexity and IT project success had a greater negative Pearson's product-moment correlation, $r = -.350$, $r^2 = .123$, $p < .001$, than did IT project complication and IT project success, $r = -.228$, $r^2 = .052$, $p < .001$. Nonparametric correlations between IT project complexity and IT project success $\tau = -.256$, $p < .001$ and $r_s = -.363$, $p < .001$ were also more strongly negative than those between IT project complication and IT project success $\tau = -.123$, $p < .01$ and $r_s = -.181$, $p < .01$.

These results confirmed the original hypothesis of a stronger negative correlation between IT project complexity and IT project success than between IT project complication and IT project success. From a theoretical standpoint, these findings confirmed the existence of separate dimensions of IT project characteristics representing IT project complexity and IT project complication. Practical implications of these findings include the insight that while complexity and complication often occur together on IT projects, they are distinct sets of project characteristics which can and should be managed differently, and high levels of IT project complexity appear more likely to lead to IT project failure than high levels of IT project complication. Implications of these findings include the recommendation that management focus on identifying, mitigating, and accommodating IT project complexity in order to increase the likelihood of IT project success.

Discussion of the Conclusions

Study findings were consistent with prior studies indicating a negative correlation between IT project complexity and IT project success, including Xia and Lee (2004) and Burkatzky (2007); however, this study extended prior research by distinguishing between IT project complexity and IT project complication, and demonstrating empirically that although they were positively correlated, they were distinct sets of project characteristics with different relationships to IT project success.

Project Complexity and Project Success

In addition to confirming the existence of separate project characteristics related to complexity and complication as defined by Cilliers (1998), results of this study confirmed that IT project complexity and IT project complication were related to each other, but represented different sets of project characteristics with different relationships to IT project success.

In this study, the project complexity model developed by Hass (2007a, 2007b, 2009) was extended and empirically tested. The 11 categories of project complexity dimensions suggested by Hass were further analyzed and categorized in the context of other studies of factors contributing to project complexity and project complication (Baccarini, 1996; Cilliers, 1998), and a model was developed that distinguished between IT project complexity and IT project complication. The model was tested and negative correlations were confirmed between IT project complexity and IT project success, and between IT project complication and IT project success.

Xia and Lee (2004) did not distinguish between complexity and complication, but instead categorized project attributes into structural and dynamic variants of organizational and IT complexity. They found significant relationships between structural organizational complexity and several dimensions of IT project success (r = -.311 to -.395, $p < .01$), but weaker and less significant relationships between dynamic organizational complexity and project cost (r = -.085, $p < .1$), and between dynamic IT complexity and functionality (r = -.091, $p < .05$). They found no correlation, however, between structural IT complexity and IT project success. By differentiating between project complexity and project complication, this study provided evidence that they had different relationships with project success, $r = -.350$, $p < .001$, and $r = -.228$, $p < .001$, respectively.

Burkatzky (2007) extended the work done by Xia and Lee (2004) by adding factors related to project manager and team member workload, project leadership, team geographic dispersion, and language barriers, but found a positive correlation between IT project complexity and system integration performance, $r = .339$, $p = .01$. The results of this study contradicted Burkatzky's findings, indicating the possibility of other confounding variables in either study, an inverse relationship between system integration performance and IT project success, or an opportunity for further factor analysis.

The Novelty-Technology-Complexity-Pace (NTCP) model, developed and expanded by Shenhar, et. al. (2005), Brockhoff (2006), Shenhar and Dvir (2007b), and Sauser, et. al. (2009), has been used to assess and categorize projects scales representing four dimensions of project complexity, but not tested empirically for relationships with project success. While some of the project attributes associated with each dimension were similar to the construct elements in this study, the NTCP model did not differentiate between complexity and complication.

Project Success Criteria

This study also contributed to the understanding of the relationship between success criteria and the perception of IT project success. Project success criteria based on the rational systems view (Fayol, 1949/1919; March & Simon, 1958; Taylor, 1919) such as the triple constraint approach utilized by the Standish Group (1994, 2009) can make complex projects appear less successful than do criteria which take into account broader organizational factors and environmental change. Particularly for complex IT projects, this study underscores the need for broader and more diverse definitions of project success.

In addition, the study results indicated the importance of selecting appropriate project success criteria. For projects with high levels of complexity, selection of appropriate project objectives and success metrics appeared to be strongly related to the ultimate perception of project success. This supported the results found by Dvir, Raz, and Shenhar (2003) indicating no correlation between formal project planning or success criteria and project success, but strong correlations between achieving internal project goals and delivering end user benefits, $r^2 = .621$, $p = .000$; contractor benefits, $r^2 = .317$, $p = .001$; and overall project success, $r^2 = .570$, $p = .000$. In addition, results indicated the importance of differentiating between success as evaluated against initial and final project baselines. For practitioners, the importance of selecting appropriate project success criteria, particularly for projects with higher degrees of complexity, is clear. From a theoretical perspective, the need is evident for further studies and empirical evidence supporting broader ranges of project success criteria for projects of differing characteristics.

Comparison of IT project success rates found in this study with those reported by the Standish Group (2009) provided further evidence that the Standish results may have overemphasized the incidence of IT project failure. When success was evaluated more broadly, and success criteria were re-baselined during project execution, IT project success may have been more common than previously reported. Study results did confirm, however, the Standish (1999) results indicating a decline in project success rates with increasing project duration and team size. From the theoretical perspective, evidence of a need for a broader definition of IT project success and a more realistic assessment of IT project success rates is indicated.

Application of Complex Adaptive Systems Theory to Project Management Theory

This study provided a comprehensive overview of project management theory from historical, organizational, and analytical perspectives. Systems paradigms from organizational theory were applied and extended with the addition of a complex adaptive systems view, providing a framework for comparing and categorizing the multiple schools of project management theory by their underlying systems paradigm. This approach confirmed that as temporary organizations, projects can be studied using the full range of organization theory and general systems theory.

In addition, this study furthered the application of complex adaptive systems theory to the study of project management theory. Building on Turner and Muller's (2003) description of projects as temporary organizations and the work of Thietart and Forgues (1995) in applying the complex adaptive systems view to the study of organizations, this study provided empirical evidence of the distinction between project complication and project complexity, and their differing relationships with project success.

Limitations of the Study

In this section, limitations of the study, including those related to the study population and sampling method, survey questions, construct elements and factors, and construct correlations, are discussed in greater detail. Following this discussion, the limitations are addressed with recommendations for further research.

Population and Sample

The sampling frame for the study was a professional organization focused on IT project management. A 100% probability sample was used to maximize sample validity, but the sample and the study population may not be representative of the intended target population, U.S.-based IT project managers, because the organization is membership-based and does not include a random sample of all U.S. IT project managers. Descriptive statistics confirmed the practitioner focus of the PMI IS CoP and found that the study population consisted primarily of project management practitioners, with those holding the titles of Project Manager and Program Manager representing 64% of the sample. The study also found that 76% of participants reported that they or the primary project manager held the Project Management Professional (PMP) certification, which was greater than the 63% found in another study of PMI members (Sumner, Bock, & Giamartino, 2006). External validity may have been further influenced by the PMI IS CoP focus on advancing the practice of IS and IT project management, and the Project Management Institute emphasis on advancing the professional certification of project managers (PMI-ISSIG, 2008; PMI IS CoP, 2011). It is possible that members of the PMI IS CoP are more advanced in project management knowledge and practices than non-members, further limiting the generalizability of the findings to the target population of U.S. IT project management practitioners.

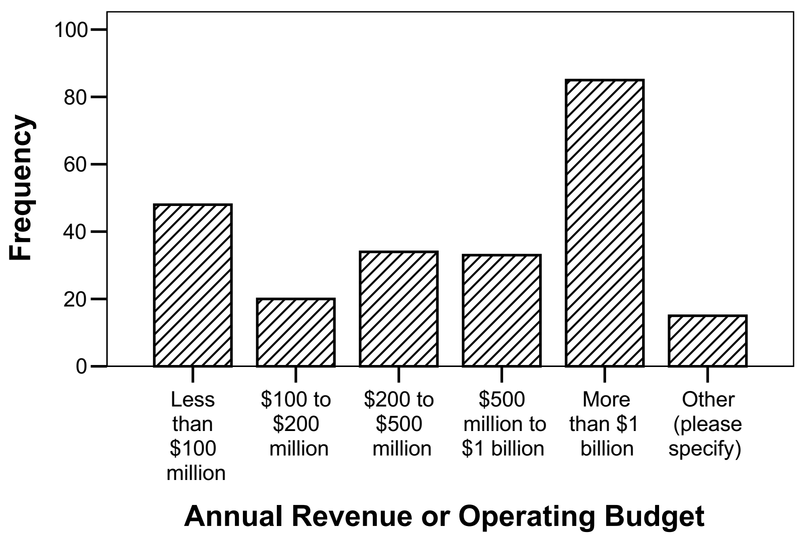
In addition, it is possible that non-response bias was present in the sample. The duration of the data collection period was set arbitrarily at 30 days based on response patterns exhibited in prior studies using the same sampling frame. Trend analysis indicated that an adequate number of responses was received in less than five days, and

88.6% of all qualified responses were received in the first 10 days. While the total number of qualified responses received, $N = 235$, was more than double the minimum sample size $n = 115$ determined by power analysis, the overall response rate of 3.9% of the 6,000 U.S.-based members of the PMI IS CoP was lower than the 6% to 15% reported for previous studies (Mishra, et al., 2009; Wallace, et al., 2004; Xia & Lee, 2005). Those who responded to the invitation to participate in the research study may have been more engaged and interested in the subject matter than non-responders, and therefore not representative of the sample as a whole. Follow-up e-mail reminders may have increased the overall response rate and reduced the possible risk to external validity attributable to non-response bias (Armstrong & Overton, 1977; Sax, et al., 2003; Suchman & McCandless, 1940).

Survey Questions

Although the survey instrument was field tested and pilot tested, data analysis revealed some potential limitations to validity and generalizability attributable to the survey questions. In general, the use of a single response choice to indicate the answer to a survey question was not applicable or unknown may have failed to distinguish between cases where a particular project characteristic was not determined for a project and those where it was simply not known to the survey participant. This distinction could have changed the results of some of the data analysis intended to determine the relationships between project characteristics and project success as measured against initial and final project baselines.

More specifically, distributions of the responses to some survey questions may have indicated a lack of clarity in the wording of the questions themselves. Survey responses for organization size displayed wide variation as well as noticeable bimodality (see Figure 15). This was possibly due to an unclear distinction in the survey question between the size of the performing organization and the size of the parent organization as a whole. Similar bimodality was also observed in participant responses for annual revenue or operating budget (see Figure



16)

Figure 16, again, possibly due to an unclear distinction in the survey question between the annual revenue or operating budget of the performing organization and the annual revenue or operating budget of the parent organization as a whole. While these limitations may not have affected the outcomes of data analysis significantly, they may have reduced the generalizability of the findings.

Construct Elements and Factors

Development of a new conceptual model and variable constructs also left room for improvement in the factors and elements used to measure some project characteristics. In particular, the discovery that the distribution for the ITPS construct was not normal indicated a possible flaw in the scales used to assess IT project success.

While they were based on scales used in similar studies including those performed by the Standish Group (2009) and White and Fortune (2002), they did not use an equal number of ordinal categories for both negative and positive project outcomes. As a result, scores tended to be clustered toward the end of the scales rather than distributed around a centrally-located mean. Had this tendency been displayed to as great an extent in the pilot study data, the scales could have been adjusted prior to data collection.

There was also room for improvement in the clarity and specificity of factor and element definitions and the number of factors and elements used to measure the remaining constructs. Extensive heteroscedasticity indicated wide variability in responses, violating prerequisite assumptions for regression analysis. Further reduction of factors through discriminant analysis could have improved the reliability of the conceptual model. The recommendations for additional research incorporate some of these opportunities for improvement.

Construct Correlations

Perhaps the greatest limitation to the overall generalizability of the study was the relatively low degree of correlation between the independent variables for IT project complexity and IT project complication, and the dependent variable for IT project success, especially in the context of the stronger correlation between the two independent variables. While the study results confirmed that IT project complexity was more strongly negatively correlated with IT project success than was IT project complication, the moderate effect sizes of the correlations and the degree of heteroscedasticity exhibited in the representative scatter plots with derived regression lines indicated that more work is needed in the future to identify the most significant factors of IT project complexity and further distinguish it from IT project complication and other confounding variables. In particular, the very low effect size of the relationship between IT project complication and IT project success could be indicative of either confounding variables or a fundamentally weak relationship between the constructs.

Recommendations for Further Research

In this section, recommendations for further research are offered, starting with those directly related to the study results. Recommendations are then made for improving upon the study limitations and expanding the study to include some areas that were intentionally delimited from the scope. Finally, suggestions are offered for additional investigation of the study concepts beyond what this study has addressed.

Recommendations from Study Results

Results of this study confirmed a distinction between IT project complexity and IT project complication. Further research is needed to refine this distinction and develop a more specific and useful model of the factors contributing to project complexity and project complication. In addition, research into project complexity and project success should continue to be extended into other types of projects as well. Further understanding of project complexity across all project types could improve project performance and success rates for all projects.

Recommendations from Limitations

Limitations of the study indicate several opportunities for improving on the study methods and outcomes. The study population was selected because it provided access to a group of IT project management practitioners who have participated reliably in prior studies. The self-selecting characteristics of the study population may have limited generalizability to the target population, U.S. IT project managers. Greater generalizability may be gained with a sample drawn from a study population more representative of the target population as a whole. In addition, in order to maximize opportunities to compare results with prior studies, the survey population was limited to U.S.-based members of the PMI IS CoP. Restricting the invitation list to U.S.-based members proved more difficult than anticipated for the IS CoP communication group, so e-mail invitations were sent to all IS CoP members. Results were filtered and only responses from members based in the U.S. were used for data analysis. Except for response rates, comparison with prior studies did not yield useful insights, so responses from all IS CoP members could have been used if IRB approval had been sought for an international sample.

An opportunity existed to either increase the total number of responses with follow-up e-mail reminders or shorten the data collection period after a sufficient number of responses were received. While follow-up reminders were not needed to obtain the minimum number of responses required, overall response rate might have been significantly greater with follow-up reminders, reducing the possibility of non-response bias. Alternatively, the data collection period could have been shortened once sufficient responses had been received.

There are also opportunities for improving on the survey questions. Further testing and refinement of demographic and organizational questions could improve generalizability and offer opportunities for further analysis of project outcomes by organizational characteristics. In addition, future researchers may want to consider providing separate responses to survey questions distinguishing between cases where a particular attribute was not measured and those where an attribute was measured but the survey respondent did not know the answer.

Scales used to measure IT project success, although based on prior studies, could be improved. Using an equal number of ordinal categories for positive and negative project outcomes might result in a distribution of aggregated scores for project success that is more normally distributed, improving the reliability of correlation analysis without requiring extensive data transformation.

Factor analysis and structured equation modeling could also reduce the heteroscedasticity of construct relationships by identifying a reduced set of factors and elements with stronger correlations. Reduced heteroscedasticity could also provide the opportunity for further regression analysis and analysis of variance in order to further refine the understanding of relationships among the study variables.

Finally, investigation into additional moderating and confounding variables could help determine whether the relationship between project complexity and project success is of primary interest, or whether there are other project characteristics having stronger correlations with project success.

Recommendations from Delimitations

The necessary restrictions on the scope of this study leave several opportunities for additional research. The literature review identified a broad range of project success definitions and criteria; however, the project success metrics used in this study were based on the triple constraint and the success criteria developed by the Standish Group (2009) and White and Fortune (2002). Further research into success rates of complex IT projects using different definitions and criteria for project success may indicate additional significant relationships between success criteria and project success. In particular, further research into success rates as measured against initial and final project baselines represents an immediate opportunity for expanding the results of this study.

Furthermore, an opportunity exists to explore more deeply the relationships between IT project characteristics and IT project success. Further investigation of correlations between individual factors of IT project complexity and different measures of IT project success could provide greater insight into the dimensions of project complexity that are most strongly related to specific project success criteria. Such evidence could advance the knowledge and practice of selecting appropriate success metrics for projects of varying degrees of complexity.

This study also did not investigate the relationships between the project and systems development methodologies used and the likelihood of success on complex IT projects. Significant opportunities for additional research exist in investigating the role of methodology selection and implementation in complex IT projects.

Finally, the study methodology itself provides a number of opportunities for further investigation and improvement. Factor analysis and structural equation modeling are methods that could improve the reliability of the study constructs, and regression analysis and analysis of variance could be applied to further investigate construct correlations.

Recommendations for Additional Investigation

Confirmation of a relationship between project complexity and success is only a starting point for further exploration into factors related to success on complex IT projects. Establishment of a tested and reliable assessment instrument for IT project complexity and project complexity in general would allow further investigation into the effects of certain project characteristics on the likelihood of success for complex projects. Such research could then be extended to include analysis of the effects of additional project characteristics such as methodology selection, technology platforms, project staffing, communication methods, and team composition on success rates for complex IT projects. Further clarification of difference between complexity and complication would facilitate the investigation of the effects of various project interventions and approaches for projects with different degrees of complexity and complication. Since these differing sets of project characteristics appear to affect project behavior quite differently, it is important that they be considered to as great an extent as possible in future research into other aspects of project behavior and outcomes.

Conclusions

As a result of the preceding analysis and results, some final recommendations for IT project management practitioners are offered. In addition, the study implications are reviewed in the larger context of organizational theory, systems theory, and project management theory.

Recommendations for Practice

Based on the results of this study, the following recommendations can be offered for IT project management practitioners. First, it may be helpful to incorporate an intentional assessment of project complexity into the initiation, planning, and execution of IT projects. Taking proactive steps to mitigate or accommodate the likely effects of IT project complexity on IT project success, such as subdividing larger projects into smaller iterations or related phases and deliverables, may help increase the likelihood of success on complex IT projects.

Second, consider the impact of methodology selection. Project management methods that work well on complicated IT projects may increase the likelihood of failure on complex IT projects. Choosing project success criteria carefully and negotiating for more appropriate success criteria on complex IT projects may also improve project success rates. Consider organizational outcomes or product success in addition to process metrics, and look for ways to accommodate the degree of change typically experienced on complex IT projects.

Third, do not assume IT project failure is as common as reported, and do not use such evidence to justify failure. Measure project performance frequently, take corrective action where needed, and negotiate changes in project success criteria where warranted. Be willing to recommend canceling a project that is no longer aligned with organizational objectives or delivering value to stakeholders.

Finally, do not lose focus on the basics. Project success, even for complex IT projects, is still related to the experience and track record of the project team, the effectiveness of requirements management, the leadership abilities of the project manager, and the support of executives and users.

Further Implications for Theory

This study began with the premise that there was a difference between complexity and complication (Cilliers, 1998). Complicated systems, processes, and organizations can be managed with traditional, rational systems-based management approaches (Fayol, 1949/1919; March & Simon, 1958; Taylor, 1919). Complex systems, processes, and organizations, however, are often unpredictable and uncontrollable (Gabriel, 1998; Lorenz, 1972). Information technology projects can be characterized as complex adaptive systems (Jaafari, 2003), but most existing project management theory and methods are based on the rational systems view. Complex adaptive systems theory has not yet been fully incorporated into general project management practice.

The results of this study furthered the understanding that the root causes of IT project failure may not be limited to ineffective application of traditional, structured project management methods and practices. Overreliance on traditional methods on complex projects may increase the likelihood of project failure. Complexity and complication are related, but fundamentally different sets of project characteristics. While complication can be managed with traditional management methods, complexity can only be mitigated. Recent trends toward shorter, smaller, faster, and less costly IT projects, incorporating more frequent incremental delivery of value and benefits (D. DeCarlo, 2004; Hass, 2009; McConnell, 1996), may reduce the risk of rapid change in economic climates, organizational objectives, and technological innovations by providing more frequent opportunities to confirm and realign organizational and project objectives.

Finally, IT project failure may not be as common as reported. The Standish Group (2009) definitions of successful, challenged, and failed IT projects may be too restrictive. Survey data from this study indicated a greater proportion of successful projects, and a much greater proportion of challenged projects. These results may indicate that challenged projects, or those that deliver most of their original scope and finish within 20% of their original budget and schedule, are actually considered successful by most practitioners. Practitioners may be adapting to changing requirements, schedules, and budgets, and still delivering value. Final project deliverables may not match the original requirements exactly, but complex adaptive systems theory allows the possibility that requirements are incomplete, incorrect, or superseded during the project life cycle.

"Complexity is the business we are in, and complexity is what limits us" (Brooks, 1995, p. 226). The emerging school of project complexity, which applies complex adaptive systems theory to project management theory and practice, broadens theoretical foundations and expands project management methods and approaches to accommodate information technology projects of increasing complexity.

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APPENDIX A. CONSTRUCT ELEMENT TABLE

Table A1

Construct Element Table

	Sources				Current study and survey			
Construct	Citation	Element	Factor	Scale	Element	Factor	Scale	Questions
IT project complexity	Hass (2009)	Clarity of problem, opportunity, and solution	Clarity of business objectives	3-category ordinal	Objectives	Clarity of project objectives	5-point ordinal Likert-type	4.1
			Understandability and definability of problem or opportunity	3-category ordinal	Opportunity or problem	Clarity of opportunity or problem	5-point ordinal Likert-type	4.2a
						Novelty of opportunity or problem	5-point ordinal Likert-type	4.2b
			Definability and familiarity of the solution	3-category ordinal	Solution	Familiarity of solution	5-point ordinal Likert-type	4.3a
						Novelty of solution	5-point ordinal Likert-type	4.3b
		Team composition and performance	Team staffed internally or externally	3-category ordinal	Staffing	Number of organizations involved	5-point ordinal Likert-type	4.12
			Team experience together	3-category ordinal	Team	Team experience	5-point ordinal Likert-type	4.5a
			Team track record	3-category ordinal		Prior team performance	5-point ordinal Likert-type	4.5b
			Methodology formality and consistency	3-category ordinal	Methodology	Methodology formality	5-point ordinal Likert-type	4.6a
						Methodology consistency	5-point ordinal Likert-type	4.6b

Table A1

Construct Element Table

	Sources				Current study and survey			
Construct	Citation	Element	Factor	Scale	Element	Factor	Scale	Questions
		Urgency and flexibility of cost, time, and scope	Schedule flexibility	3-category ordinal	Schedule	Schedule reasonableness	5-point ordinal Likert-type	4.4a
						Schedule flexibility	5-point ordinal Likert-type	4.4b
		Requirements volatility and risk	Requirements understood	3-category ordinal	Requirements	Requirements clarity	5-point ordinal Likert-type	4.7a
			Requirements subject to change	3-category ordinal		Requirements volatility	5-point ordinal Likert-type	4.7b
		Level of organizational change	Number of business processes affected	3-category ordinal	Organizational change	Business processes affected	5-point ordinal Likert-type	4.8
			Extent of organizational change	3-category ordinal		Degree of organizational change	5-point ordinal Likert-type	4.9
		Level of commercial change	Changes to commercial practices	3-category ordinal	Technological change	Degree of technological change	5-point ordinal Likert-type	4.10
		Strategic importance, political implications, multiple stakeholders	Political implications	3-category ordinal	Environment	Political importance	5-point ordinal Likert-type	4.13a
			Impact on mission	3-category ordinal		Strategic importance	5-point ordinal Likert-type	4.13b
			Number of stakeholder groups	3-category ordinal		Stakeholder diversity	5-point ordinal Likert-type	4.13c

Table A1

Construct Element Table

	Sources				Current study and survey			
Construct	Citation	Element	Factor	Scale	Element	Factor	Scale	Questions
		Risks, dependencies, and external constraints	Project risk	3-category ordinal		External dependencies	5-point ordinal Likert-type	4.13d
			External influences	3-category ordinal				
			Integration issues	3-category ordinal				
			Regulatory changes	3-category ordinal		Regulatory change	5-point ordinal Likert-type	4.13e
			Punitive exposure	3-category ordinal		Legal exposure	5-point ordinal Likert-type	4.13f
		Level of IT complexity	Solution achievability and familiarity	3-category ordinal	IT complexity	Degree of IT innovation	5-point ordinal Likert-type	4.14a
			IT complexity and legacy integration	3-category ordinal		Degree of IT complexity	5-point ordinal Likert-type	4.14b
		Requirements volatility and risk	Complexity of functionality	3-category ordinal				
		Level of IT complexity	IT complexity and legacy integration	3-category ordinal	IT integration	Number of interfaces with other systems	5-point ordinal Likert-type	4.11
IT project complication	Hass (2009)	Time/cost	Project duration	3-category ordinal	Duration	Project duration	5-point ordinal Likert-type	5.2
			Project cost	3-category ordinal	Cost	Project cost	5-point ordinal Likert-type	5.4

Table A1

Construct Element Table

	Sources				Current study and survey			
Construct	Citation	Element	Factor	Scale	Element	Factor	Scale	Questions
		Team size	Number of team members	3-category ordinal	Team size	Team size	5-point ordinal Likert-type	5.3
		Team composition and performance	Project leader competence and experience	3-category ordinal	Leadership	Project leader experience	5-point ordinal Likert-type	5.1a
						Project leader competence	5-point ordinal Likert-type	5.1b
			Contract complexity, contractor performance	3-category ordinal	Contracts	Number of contracts	5-point ordinal Likert-type	5.10
						Contractor familiarity	5-point ordinal Likert-type	5.11a
						Contractor performance	5-point ordinal Likert-type	5.11b
		Urgency and flexibility of cost, time, and scope	Scope ambitiousness and flexibility	3-category ordinal	Scope	Scope flexibility	5-point ordinal Likert-type	5.6
			Budget flexibility	3-category ordinal	Cost	Budget flexibility	5-point ordinal Likert-type	5.5
		Level of organizational change	Organizational units affected	3-category ordinal	Organizational support	Organizational units affected	5-point ordinal Likert-type	5.9
		Strategic importance, political implications, multiple	Number of stakeholder groups	3-category ordinal				
			Communications difficulty	3-category ordinal				

Table A1

Construct Element Table

	Sources				Current study and survey			
Construct	Citation	Element	Factor	Scale	Element	Factor	Scale	Questions
		stakeholders	Executive support	3-category ordinal		Executive support	5-point ordinal Likert-type	5.8a
		Requirements volatility and risk	Customer/user support	3-category ordinal		User support	5-point ordinal Likert-type	5.8b
		Level of organizational change	Number of IT systems affected	3-category ordinal	Technology	Technology percentage of scope	5-point ordinal Likert-type	5.7
IT project success	Standish Group (1994, 1999)	Successful	Completed on time and on budget, with all features and functions as initially specified	Yes/No, 6-point Likert	Performance against original plans and goals (Baseline 1)	Percent of original schedule	5-point ordinal Likert-type	6.2a
						Percent of original budget	5-point ordinal Likert-type	6.2b
						Percent of original scope	5-point ordinal Likert-type	6.3
		Challenged	Completed and operational but over budget, late, with fewer features and functions than originally specified	Yes/No, 6-point ordinal Likert-type	Performance against final plans and goals (Baseline n)	Percent of final schedule	5-point ordinal Likert-type	6.4a
						Percent of final budget	5-point ordinal Likert-type	6.4b
						Percent of final scope	5-point ordinal Likert-type	6.5
		Failed	Canceled before completion or never	Yes/No, 6-point	Completion	Degree of completion	5-point ordinal Likert-type	6.1

Table A1

Construct Element Table

	Sources				Current study and survey			
Construct	Citation	Element	Factor	Scale	Element	Factor	Scale	Questions
			implemented	ordinal Likert-type	Implementa-tion	Degree of implementation	5-point ordinal Likert-type	6.6
Demographic information	Standish Group (1994, 1999)	Annual Revenue	Annual revenue	5-category ordinal	Annual Revenue	Annual revenue or operating budget	5-category ordinal	7.2
	White and Fortune (2002)	Industry Sector	Industry Sectors	List	Industry Sector	Industry Sectors	List	7.1
		Project Type	Project Types	List	Project Type	Project Types	List	7.4
		Employees	Number of employees	5 categories	Employees	Number of employees	5 categories	7.3
		Title	Your title	List	Title	Your title	List	7.5
		Role	Your role in the project	List	Role	Your role in the project	List	7.6
					PMP Certification	You	2 categories	7.7a
						Project manager	2 categories	7.7b

APPENDIX B. PARTICIPANT ACCESS

Participant access for the study is provided through the PMI IS CoP. A sample e-mail invitation to participants is including beginning on the following page.

Sample E-Mail Invitation to PMI IS CoP Members

From: Project Management Institute <donotreply@pmi.org>

To: <e-mail address>

Date: <date>

Subject: PMI IS CoP Research Study on IT Project Complexity

IT Project Managers Needed for a Brief Survey on Project Complexity and Project Success

Please consider sharing the benefits of your IT project management experience by participating in a new study of project complexity, project complication, and project success being performed by a fellow PMI IS CoP member, practicing IT project and program manager, and doctoral student at Capella University.

What is the purpose of the study?

This study investigates the relationships between IT project complexity, IT project complication, and IT project success. It distinguishes between project complication and project complexity and then compares their relationships with project success to help determine what project characteristics contribute to complexity and complication, and how they influence project success and failure.

Who is invited to participate?

All U.S.-based project managers with experience managing at least one IT project.

What are the benefits of participating?

You will help advance the current understanding of project complexity and how it affects success on IT projects.

You will gain a better understanding of the difference between project complexity and project complication, and the project characteristics that tend to contribute to them.

You will have an opportunity to request a copy of the study results. No personal identification information will be captured in the survey.

How can I participate?

You can access the survey now at <survey link>. Completing the survey will take approximately 10 to 15 minutes.

When the survey available?

The survey is open for participation now, and will remain open for 30 days until <date>.

How can I get more information?

For more information on the survey or the study, contact David Williamson at <e-mail address>.

APPENDIX C. INFORMED CONSENT AND SURVEY INSTRUMENT

The survey was hosted online by SurveyMonkey. A printed version of the online survey including the introduction and statement of informed consent begins on the following page.

IT Project Complexity, Complication, and Success

1. About this Study

My name is David J. Williamson and I am a doctoral learner in the School of Business and Technology at Capella University. I am also a practicing IT project and program manager, a member of the Project Management Institute (PMI), a certified Project Management Professional (PMP), and a member of the PMI Information Systems Community of Practice (IS CoP).

I am performing a research study entitled ***A Correlational Study of the Relationships among Information Technology Project Complexity, Project Complication, and Project Success***. This research is being supervised by Dr. Lawrence W. Ness.

You are invited to participate in this research study. The main purpose of this page is to provide information about the research so that you can make a decision about whether you want to participate.

What is the Research About?

The purpose of this study is to examine the relationships between information technology (IT) project complexity, project complication, and project success in order to help improve the understanding of project characteristics that contribute to project complexity and project complication, how project complexity and project complication differ, and how they influence project success. Ultimately, this may contribute to more effective project management practices and project success measures for complex IT projects.

Why are You Being Asked to Participate?

You have been invited to participate because you are a project manager and/or a member of the Project Management Institute's Information Systems Community of Practice (PMI IS CoP).

Please click on the "Next" button below to proceed to the Statement of Informed Consent.

IT Project Complexity, Complication, and Success

2. Informed Consent Agreement

If you choose to participate, please click on the link at the bottom of this page to indicate your understanding and consent.

What Does Participation in this Research Study Involve?

If you choose to participate in this study, you will be asked to respond to a series of survey questions. Your participation will take about 10 to 15 minutes.

What are the Risks Involved in this Study?

Although no study can be totally risk-free, we don't anticipate that you will be harmed or distressed by participating in this research. If you find yourself becoming uncomfortable, you may stop your participation at any time.

Are there Any Benefits to Participation?

All research contributes knowledge, and some research directly benefits participants. If you participate in this research, you may find your understanding of project complexity is enhanced.

What Happens if the Researcher Gets More Information During the Study?

The researcher will contact all invited participants if he learns any new information that could change your decision about participating in this study.

How Will the Researcher Protect Participants' Confidentiality?

The results of the research study will be published, but no information identifying any participant will be revealed. Your name or identity will not be recorded.

In order to maintain confidentiality of your records, the researcher will ensure that access to survey data is limited to the researcher and his supervisor. Precautions will be taken during the survey and data analysis to ensure your privacy. Copies of survey responses will be archived electronically for a minimum of seven years. The original data will not be released to any other party for any reason without the written consent of the study participant.

What Happens if a Participant Doesn't Want to Continue in the Study?

Participation in this study is voluntary. If you choose not to participate or to withdraw from the study, you may do so at any time. There will be no consequence for choosing not to participate or withdrawing.

Will it Cost Anything to Participate in the Study? Will I get Paid?

It will not cost you anything to participate in this research study. You will not receive financial compensation for your participation.

Will Participants be Compensated for Illness or Injury?

You are not waiving any of your legal rights if you agree to participate in this study; however no funds have been set aside to compensate you in the event of harm. If you suffer harm because of this research project, you may contact David Williamson at 1-540-632-2359. You may also contact the Capella Human Research Protections Office at 1-888-227-3552, extension 4716.

IT Project Complexity, Complication, and Success

Voluntary Consent

By clicking on the "Next" button below, you are saying that you have read this form or have had it read to you, that you understand the risks and benefits of this research study, and that you know what you are being asked to do. The researcher will gladly answer any questions you have about the research. If you have any questions, please feel free to contact David Williamson at 1-540-632-2359, or Lawrence Ness at 1-615-283-8513.

If you have questions about your rights as a research participant, the Capella Human Research Protections Office is available to help. If you have any concerns about the research process or the researcher, please contact us at 1-888-227-3552, extension 4716. If there are any unexpected problems with the research please be sure to contact us. Your identity, questions, and concerns will be kept confidential.

By clicking on the "Next" button below, you are certifying that you are 18 years old or older, and that you have read this information and understand what you are being asked to do. Please print a copy of this consent information for your records.

IT Project Complexity, Complication, and Success

3. Instructions

Thank you for agreeing to participate in this survey.

IT Project Complexity and Project Complication

Despite sounding similar, project complexity and project complication may represent different sets of project characteristics. The following questions are intended to assess the complexity and complication of your most recent information technology project.

Your Most Recent IT Project

When you answer the questions in the survey, please think about the most recent completed or canceled information technology project with which you were involved.

It is not necessary for you to select a project which was considered successful.

The purpose of this research is to investigate the relationship between project complexity, project complication, and project success. Answering the survey questions candidly and truthfully about your most recent completed or canceled project, whether successful, troubled, or unsuccessful, will provide valuable data for this study.

Please click on the "Next" button below to begin the survey.

IT Project Complexity, Complication, and Success

4. IT Project Complexity

The following set of questions are intended to assess IT project complexity.

When you answer the questions, please consider the most recent completed or canceled IT project with which you were involved.

1. Project Objectives

At the time the project started, the project objectives:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Were clear and understandable.	◯	◯	◯	◯	◯	◯

2. Project Opportunity or Problem

At the time the project started, the project opportunity or problem:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Was clear and understandable.	◯	◯	◯	◯	◯	◯
Was familiar to our organization.	◯	◯	◯	◯	◯	◯

3. Project Solution

At the time the project started, the project solution or technology:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Was familiar to our organization.	◯	◯	◯	◯	◯	◯
Was readily available.	◯	◯	◯	◯	◯	◯

4. Project Schedule

At the time the project started, the original project schedule:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Was reasonable.	◯	◯	◯	◯	◯	◯
Was flexible.	◯	◯	◯	◯	◯	◯

IT Project Complexity, Complication, and Success

5. Project Team: Experience and Performance

At the time the project started, the project team:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Had relevant experience.	○	○	○	○	○	○
Had a track record of success on similar projects.	○	○	○	○	○	○

6. Project Methodology: Formality and Consistency

The project management and/or systems development methodologies used by the team:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Were formal and documented.	○	○	○	○	○	○
Were consistent with other projects performed by our organization.	○	○	○	○	○	○

7. Project Requirements: Clarity and Stability

The project requirements:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Were clear and understandable.	○	○	○	○	○	○
Were stable and did not change during the project.	○	○	○	○	○	○

8. Business Processes

What proportion of the organization's business processes were affected by the project?

	Very Low	Low	Average	High	Very High	N/A or Unknown
Proportion of business processes affected:	○	○	○	○	○	○

IT Project Complexity, Complication, and Success

9. Organizational Change

What was the extent of organizational change caused by the project?

	Very Low	Low	Average	High	Very High	N/A or Unknown
Extent of organizational change:	◯	◯	◯	◯	◯	◯

10. Technological Change

What proportion of the project scope was new technology, or technology that was unfamiliar to the organization?

	Very Low	Low	Average	High	Very High	N/A or Unknown
Proportion of new or unfamiliar technology:	◯	◯	◯	◯	◯	◯

11. IT Integration: Number of Interfaces

How many interfaces to other systems were included in the project scope/design?

	None	1-2	3-5	5-7	More than 7	N/A or Unknown
Number of interfaces:	◯	◯	◯	◯	◯	◯

12. Project Staffing: Number of Organizations

Aside from your organization, how many additional organizations including partners, suppliers, contractors, advisors, customers, etc. were involved with the project?

	None	1-2	3-5	5-7	More than 7	N/A or Unknown
Number of additional organizations:	◯	◯	◯	◯	◯	◯

IT Project Complexity, Complication, and Success

13. Project Environment

To what extent did the following project environmental characteristics affect the project?

	Very Low	Low	Average	High	Very High	N/A or Unknown
Political importance:	◯	◯	◯	◯	◯	◯
Strategic importance:	◯	◯	◯	◯	◯	◯
Stakeholder conflicts:	◯	◯	◯	◯	◯	◯
External dependencies:	◯	◯	◯	◯	◯	◯
Regulatory change:	◯	◯	◯	◯	◯	◯
Legal exposure/risk:	◯	◯	◯	◯	◯	◯

14. IT Complexity

What was the extent of IT complexity and IT innovation on the project?

	Very Low	Low	Average	High	Very High	N/A or Unknown
IT complexity:	◯	◯	◯	◯	◯	◯
IT innovation:	◯	◯	◯	◯	◯	◯

IT Project Complexity, Complication, and Success

5. IT Project Complication

The next set of questions are intended to assess IT project complication.

When you answer the questions, please consider the same completed or canceled IT project you described in the first set of questions.

1. Project Leadership

At the time the project started, the project leader:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Had relevant experience.	◯	◯	◯	◯	◯	◯
Was competent.	◯	◯	◯	◯	◯	◯

2. Project Duration

What was the originally planned project duration?

	Less than 3 Months	3-6 Months	6-9 Months	9-12 Months	More than 12 Months	N/A or Unknown
Originally planned project duration:	◯	◯	◯	◯	◯	◯

3. Project Team Size

What was the originally planned team size?

	Less than 3 Members	3-4 Members	5-10 Members	11-15 Members	More than 15 Members	N/A or Unknown
Originally planned team size:	◯	◯	◯	◯	◯	◯

4. Project Cost or Budget

What was the originally planned project cost or budget (in US$)?

	Less than $250,000	$250,000-$500,000	$500,000-$750,000	$750,000-$1,000,000	More than $1,000,000	N/A or Unknown
Originally planned project cost or budget:	◯	◯	◯	◯	◯	◯

IT Project Complexity, Complication, and Success

5. Project Cost or Budget Flexiblity

How flexible were the originally planned project cost or budget?

	Very Low	Low	Average	High	Very High	N/A or Unknown
Flexibility of original project cost or budget:	◯	◯	◯	◯	◯	◯

6. Project Scope Flexiblity

How flexible was the originally planned project scope?

	Very Low	Low	Average	High	Very High	N/A or Unknown
Flexibility of original project scope:	◯	◯	◯	◯	◯	◯

7. Technology Scope

What percentage of the project scope consisted of technology development or implementation (vs. organizational change or business process change)?

	0-20%	20-40%	40-60%	60-80%	80-100%	N/A or Unknown
Technology percent of scope:	◯	◯	◯	◯	◯	◯

8. Organizational Support

How strong was the support for the project from executives and users?

	Very Low	Low	Average	High	Very High	N/A or Unknown
Executive support:	◯	◯	◯	◯	◯	◯
User support:	◯	◯	◯	◯	◯	◯

9. Organizational Units Affected

How many organizational units within your organization were involved or affected by the project?

	None	1-2	3-5	5-7	More than 7	N/A or Unknown
Number of organizational units involved or affected:	◯	◯	◯	◯	◯	◯

10. Contracts: Number of Contractors

How many different contracts or contract organizations were used on the project?

	None	1-2	3-5	5-7	More than 7	N/A or Unknown
Number of contracts or contract organizations:	◯	◯	◯	◯	◯	◯

11. Contracts: Contractor Familiarity and Prior Performance

The contractors used on the project:

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	N/A or Unknown
Were familiar to the organization.	◯	◯	◯	◯	◯	◯
Had a track record of success on similar projects.	◯	◯	◯	◯	◯	◯

IT Project Complexity, Complication, and Success

6. IT Project Success

The next set of questions are intended to assess IT project success.

When you answer the questions, please consider the same completed or canceled IT project you described in the previous two sets of questions.

1. Project Completion

To what extent was the project completed?

	Less than 25% Completed	25-49% Completed	50-74% Completed	75-99% Completed	100% or more Completed	N/A or Unknown
Project completion:	◯	◯	◯	◯	◯	◯

2. Project Schedule and Cost vs. ORIGINAL Plan

At the time the project was completed or canceled, please compare the actual project schedule and cost with the ORIGINAL plan or goals.

	On or under ORIGINAL plan	Less than 20% over ORIGINAL plan	21-50% over ORIGINAL plan	51-100% over ORIGINAL plan	More than 100% over ORIGINAL plan	N/A or Unknown
Project schedule vs. ORIGINAL plan:	◯	◯	◯	◯	◯	◯
Project cost vs. ORIGINAL plan:	◯	◯	◯	◯	◯	◯

3. Project Scope vs. ORIGINAL Plan

At the time the project was completed or canceled, please compare the actual project scope delivered with the ORIGINAL plan or goals.

	Less than 25% of ORIGINAL plan	25-49% of ORIGINAL plan	50-74% of ORIGINAL plan	75-99% of ORIGINAL plan	100% or more of ORIGINAL plan	N/A or Unknown
Project scope vs. ORIGINAL plan:	◯	◯	◯	◯	◯	◯

IT Project Complexity, Complication, and Success

4. Project Schedule and Cost vs. FINAL Plan

At the time the project was completed or canceled, please compare the project schedule and cost with the FINAL plan or goals.

	On or under FINAL plan	Less than 20% over FINAL plan	21-50% over FINAL plan	51-100% over FINAL plan	More than 100% over FINAL plan	N/A or Unknown
Project schedule vs. FINAL plan:	◯	◯	◯	◯	◯	◯
Project cost vs. FINAL plan:	◯	◯	◯	◯	◯	◯

5. Project Scope vs. FINAL Plan

At the time the project was completed or canceled, please compare the project scope delivered with the FINAL plan or goals.

	Less than 25% of FINAL plan	25-49% of FINAL plan	50-74% of FINAL plan	75-99% of FINAL plan	100% or more of FINAL plan	N/A or Unknown
Project scope:	◯	◯	◯	◯	◯	◯

6. Project Implementation

To what extent were the results of the project implemented?

	Less than 25% Implemented	25-49% Implemented	50-74% Implemented	75-99% Implemented	100% or more Implemented	N/A or Unknown
Project implementation:	◯	◯	◯	◯	◯	◯

IT Project Complexity, Complication, and Success

7. Demographic Information

Please provide the following information for purposes of classification and analysis.

This information is confidential.

1. Industry Sector

Please identify the industry sector of the organization performing the project:

- ◯ Construction
- ◯ Defense
- ◯ Education
- ◯ Electricity, Gas, and Water
- ◯ Engineering
- ◯ Finance, Insurance, and Banking
- ◯ Health
- ◯ Information Technology
- ◯ Manufacturing
- ◯ Other Services
- ◯ Petrochemical
- ◯ Public Administration
- ◯ Publishing/Distribution
- ◯ Research and Development
- ◯ Software Development
- ◯ Transportation and Communication
- ◯ Wholesale and Retail
- ◯ Other (please specify)

IT Project Complexity, Complication, and Success

2. Annual Revenue or Operating Budget

Please select the annual revenue or operating budget of the organization performing the project:

- ◯ Less than $100 million
- ◯ $100 to $200 million
- ◯ $200 to $500 million
- ◯ $500 million to $1 billion
- ◯ More than $1 billion
- ◯ Other (please specify)

3. Number of Employees

Please select the number of employees in the organization performing the project:

- ◯ Fewer than 10
- ◯ 10 - 99
- ◯ 100 - 499
- ◯ 500 - 999
- ◯ 1,000 or More
- ◯ Other (please specify)

4. Project Type

Please identify the project type:

- ◯ Software Development
- ◯ Research and Development
- ◯ Information Technology
- ◯ Engineering
- ◯ Business Change/Reorganization
- ◯ Application Package Implementation
- ◯ Other (please specify)

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5. Your Title

Please select your title:

- ◯ Project Manager
- ◯ Program Manager
- ◯ Senior Manager
- ◯ Manager
- ◯ Director
- ◯ Team Leader
- ◯ Consultant
- ◯ Other (please specify)

6. Your Role in the Project

Please select your role on the project:

- ◯ Project Manager
- ◯ Program Manager
- ◯ Project Team Member
- ◯ Project Sponsor
- ◯ Consultant
- ◯ Stakeholder or Customer
- ◯ Other (please specify)

7. Project Management Certification

Please indicate whether the project manager was a certified Project Management Professional (PMP).

If you were the project manager, please indicate whether you were PMP certified at the time you managed the project.

	PMP Certified	Not PMP Certified	N/A or Unknown
The project manager was:	◯	◯	◯

IT Project Complexity, Complication, and Success

8. PMI IS CoP Membership (formerly PMI-ISSIG)

Please indicate whether you are a PMI Information Systems Commmunity of Practice (IS CoP) member.

The PMI IS CoP was formerly named the PMI Information Systems Special Interest Group (PMI-ISSIG).

	Yes	No	N/A or Unknown
I am a PMI IS CoP (formerly PMI-ISSIG) member.	◯	◯	◯

9. Your Location

Please indicate whether your primary work location is in the United States (US) or another location.

◯ US

◯ Other (please specify)

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8. Optional Comments

If you would like to make additional comments or provide feedback on the survey or the study, please enter your comments below.

1. Optional Comments

Are there any other comments you would like to make or feedback you would like to provide regarding this study?

You do not need to provide any contact information to leave a comment.

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9. Thank You

Thank you for participating in this survey.

Clicking "Done" below will submit your responses.

APPENDIX D. DESCRIPTIVE STATISTICS

Table D1

Industry Frequency Distribution

Industry	*n*	%
Finance, Insurance, and Banking	51	21.70
Information Technology	48	20.43
Health	27	11.49
Other	25	10.64
Manufacturing	19	8.09
Education	14	5.96
Software Development	12	5.11
Electricity, Gas, and Water	9	3.83
Defense	6	2.55
Wholesale and Retail	5	2.13
Public Administration	4	1.70
Publishing/Distribution	4	1.70
Transportation and Communication	3	1.28
Engineering	3	1.28
Petrochemical	2	.85
Research and Development	2	.85
Construction	1	.43
Total	235	100.00

Table D2

Project Type Frequency Distribution

Project type	*n*	%
Information Technology	92	39.15
Software Development	77	32.77
Application Package Implementation	26	11.06
Other	19	8.09
Business Change/Reorganization	18	7.66
Engineering	3	1.28
Total	235	100.00

Table D3

Job Title Frequency Distribution

Title	*n*	%
Project Manager	109	46.38
Program Manager	41	17.45
Director	26	11.06
Consultant	14	5.96
Other	14	5.96
Manager	13	5.53
Senior Manager	11	4.68
Team Leader	7	2.98
Total	235	100.00

Table D4

Project Role Frequency Distribution

Project role	*n*	%
Project Manager	130	55.32
Program Manager	59	25.11
Project Team Member	17	7.23
Other	12	5.11
Consultant	11	4.68
Stakeholder or Customer	3	1.28
Project Sponsor	3	1.28
Total	235	100.00

Table D5

Project Manager Certification Frequency Distribution

PMP certified	*n*	%
Yes	178	75.74
No	46	19.57
N/A or Unknown	11	4.68
Total	235	100.00

Table D6

ITPCx1 Objectives Response Distribution and Statistics

Element	ITPCx1 Objectives ($M = 2.23$)	
Factor/Scale	Score	ITPCx1 Clarity %
1 *(Disagree Strongly)*	5	3.40
2 *(Disagree)*	4	17.02
3 *(Neutral)*	3	6.81
4 *(Agree)*	2	44.26
5 *(Agree Strongly)*	1	28.52
N/A		
Total		100.00

Table D7

ITPCx2 Opportunity Response Distribution and Statistics

Element	ITPCx2 Opportunity (M = 2.06)		
Factor/Scale	Score	ITPCx2a Clarity %	ITPCx2b Familiarity %
1 *(Disagree Strongly)*	5	.85	2.98
2 *(Disagree)*	4	8.51	13.62
3 *(Neutral)*	3	8.09	8.94
4 *(Agree)*	2	48.51	46.38
5 *(Agree Strongly)*	1	34.04	27.66
N/A			.43
Total		100.00	100.00
Mean		1.94	2.18

Table D8

ITPCx3 Solution Response Distribution and Statistics

Element	ITPCx3 Solution ($M = 2.57$)		
Factor/Scale	Score	ITPCx3a Familiarity %	ITPCx3b Availability %
1 *(Disagree Strongly)*	5	8.51	7.23
2 *(Disagree)*	4	25.53	18.30
3 *(Neutral)*	3	11.49	14.47
4 *(Agree)*	2	31.49	34.89
5 *(Agree Strongly)*	1	22.55	24.26
N/A		.43	.85
Total		100.00	100.00
Mean		2.66	2.49

Table D9

ITPCx4 Team Response Distribution and Statistics

Element	ITPCx4 Team ($M = 2.48$)		
Factor/Scale	Score	ITPCx4a Experience %	ITPCx4b Track Record %
1 *(Disagree Strongly)*	5	3.83	8.09
2 *(Disagree)*	4	17.02	19.15
3 *(Neutral)*	3	14.04	19.57
4 *(Agree)*	2	40.43	32.77
5 *(Agree Strongly)*	1	24.68	20.42
N/A			
Total		100.00	100.00
Mean		2.35	2.62

Table D10

ITPCx5 Methodology Response Distribution and Statistics

Element	ITPCx5 Methodology ($M = 2.34$)		
Factor/Scale	Score	ITPCx5a Formal %	ITPCx5b Consistent %
1 *(Disagree Strongly)*	5	7.66	3.40
2 *(Disagree)*	4	16.60	11.49
3 *(Neutral)*	3	13.62	7.66
4 *(Agree)*	2	42.55	53.19
5 *(Agree Strongly)*	1	19.57	23.40
N/A			.85
Total		100.00	100.00
Mean		2.50	2.18

Table D11

ITPCx6 Schedule Response Distribution and Statistics

Element		ITPCx6 Schedule (*M* = 3.08)	
Factor/Scale	Score	ITPCx6a Reasonable %	ITPCx6b Flexible %
1 *(Disagree Strongly)*	5	12.77	15.32
2 *(Disagree)*	4	28.94	31.49
3 *(Neutral)*	3	10.21	17.02
4 *(Agree)*	2	39.57	26.38
5 *(Agree Strongly)*	1	8.51	9.36
N/A			.43
Total		100.00	100.00
Mean		2.98	3.17

Table D12

ITPCx7 Requirements Response Distribution and Statistics

Element	ITPCx7 Requirements ($M = 3.20$)		
Factor/Scale	Score	ITPCx7a Clear %	ITPCx7b Stable %
1 *(Disagree Strongly)*	5	6.38	23.40
2 *(Disagree)*	4	22.98	46.38
3 *(Neutral)*	3	17.45	10.64
4 *(Agree)*	2	42.13	14.89
5 *(Agree Strongly)*	1	11.06	4.68
N/A			
Total		100.00	100.00
Mean		2.72	3.69

Table D13

ITPCx8 Environment Response Distribution and Statistics

Element		ITPCx8 Environment ($M = 3.32$)					
Factor/Scale	Score	ITPCx8a Pol. %	ITPCx8b Strat. %	ITPCx8c S/H %	ITPCx8d Dep. %	ITPCx8e Reg. %	ITPCx8f Legal %
1 *(Very Low)*	1	6.38	1.70	5.96	5.53	34.47	22.55
2 *(Low)*	2	9.79	5.96	17.87	14.47	22.13	25.53
3 *(Average)*	3	17.87	15.74	31.91	26.81	17.87	17.02
4 *(High)*	4	26.81	37.87	25.11	29.79	10.21	17.02
5 *(Very High)*	5	37.87	38.72	18.72	22.98	9.79	14.47
N/A		1.28		.43	.43	5.53	3.40
Total		100.00	100.00	100.00	100.00	100.00	100.00
Mean		3.81	4.06	3.33	3.50	2.35	2.74

Table D14

ITPCx9 IT Response Distribution and Statistics

Element		ITPCx9 IT (*M* = 3.55)	
Factor/Scale	Score	ITPCx9a Complexity %	ITPCx9b Innovation %
1 *(Very Low)*	1	1.70	3.40
2 *(Low)*	2	4.68	15.74
3 *(Average)*	3	34.47	34.89
4 *(High)*	4	36.60	32.34
5 *(Very High)*	5	22.55	12.77
N/A			.85
Total		100.00	100.00
Mean		3.74	3.36

Table D15

ITPCx10 Technology Response Distribution and Statistics

Element	ITPCx10 Technology ($M = 3.28$)	
Factor/Scale	Score	ITPCx10 Change %
1 *(Very Low)*	1	8.94
2 *(Low)*	2	22.55
3 *(Average)*	3	20.00
4 *(High)*	4	27.66
5 *(Very High)*	5	20.43
N/A		.43
Total		100.00

Table D16

ITPCx11 Organization Change Response Distribution and Statistics

Element	ITPCx11 Org. Change (M = 3.15)		
Factor/Scale	Score	ITPCx11a Bus. Proc. %	ITPCx11b Scope %
1 *(Very Low)*	1	4.68	18.30
2 *(Low)*	2	17.45	24.26
3 *(Average)*	3	28.94	22.13
4 *(High)*	4	24.26	21.28
5 *(Very High)*	5	24.26	11.91
N/A		.43	2.13
Total		100.00	100.00
Mean		3.46	2.84

Table D17

ITPCx12 Staffing Response Distribution and Statistics

Element	ITPCx12 Staffing (M = 3.30)	
Factor/Scale	Score	ITPCx12 Organizations %
1 *(None)*	1	5.11
2 *(1-2)*	2	24.68
3 *(3-5)*	3	31.49
4 *(5-7)*	4	12.34
5 *(More than 7)*	5	26.38
N/A		
Total		100.00

Table D18

ITPCx13 IT Integration Response Distribution and Statistics

Element	ITPCx13 Integration ($M = 3.33$)	
Factor/Scale	Score	ITPCx13 Interfaces %
1 *(None)*	1	6.81
2 *(1-2)*	2	19.57
3 *(3-5)*	3	32.77
4 *(5-7)*	4	12.34
5 *(More than 7)*	5	26.38
N/A		2.13
Total		100.00

Table D19

ITPCn1 Project Leadership Response Distribution and Statistics

Element	ITPCn1 Leadership (*M* = 2.01)		
Factor/Scale	Score	ITPCn1a Experience %	ITPCn1b Competence %
1 *(Disagree Strongly)*	5	5.11	3.40
2 *(Disagree)*	4	9.79	6.81
3 *(Neutral)*	3	10.64	6.81
4 *(Agree)*	2	41.70	39.57
5 *(Agree Strongly)*	1	32.34	42.98
N/A		.43	.43
Total		100.00	100.00
Mean		2.13	1.88

Table D20

ITPCn2 Project Duration Response Distribution and Statistics

Element	ITPCn2 Duration (M = 3.27)	
Factor/Scale	Score	ITPCn2 Duration %
1 *(Less than 3 Months)*	1	8.94
2 *(3-6 Months)*	2	24.68
3 *(6-9 Months)*	3	19.57
4 *(9-12 Months)*	4	23.40
5 *(More than 12 Months)*	5	22.98
N/A		.43
Total		100.00

Table D21

ITPCn3 Team Size Response Distribution and Statistics

Element	ITPCn3 Team Size (M = 3.57)	
Factor/Scale	Score	ITPCn3 Size %
1 *(Less than 3 Members)*	1	3.83
2 *(3-4 Members)*	2	14.47
3 *(5-10 Members)*	3	36.17
4 *(11-15 Members)*	4	12.34
5 *(More than 15 Members)*	5	33.19
N/A		
Total		100.00

Table D22

ITPCn4 Cost Response Distribution and Statistics

Element			ITPCn4 Cost (M = 3.23)		
Factor/Scale	Score	ITPCn4a Planned %	Factor/Scale	Score	ITPCn4b Flexibility %
1 *(Less than $250,000)*	1	25.11	1 *(Very Low)*	5	15.32
2 *($250,000 - $500,000)*	2	16.60	2 *(Low)*	4	28.94
3 *($500,000 - $750,000)*	3	7.23	3 *(Average)*	3	37.45
4 *($750,000 - $1,000,000)*	4	7.23	4 *(High)*	2	8.09
5 *(More than $1,000,000)*	5	32.77	5 *(Very High)*	1	4.68
N/A		11.06	N/A		5.53
Total		100.00			100.00
Mean		3.07			3.45

Table D23

ITPCn5 Scope Response Distribution and Statistics

Element	ITPCn5 Scope (M = 3.26)	
Factor/Scale	Score	ITPCn5 Flexibility %
1 *(Very Low)*	5	11.91
2 *(Low)*	4	27.23
3 *(Average)*	3	42.55
4 *(High)*	2	11.06
5 *(Very High)*	1	6.81
N/A		.43
Total		100.00

Table D24

ITPCn6 Technology Response Distribution and Statistics

Element	ITPCn6 Technology (M = 3.62)	
Factor/Scale	Score	ITPCn5 Scope %
1 *(0-20%)*	1	6.81
2 *(20-40%)*	2	11.06
3 *(40-60%)*	3	42.55
4 *(60-80%)*	4	27.23
5 *(80-100%)*	5	11.92
N/A		.43
Total		100.00

Table D25

ITPCn7 Support Response Distribution and Statistics

Element	ITPCn7 Support (M = 2.28)		
Factor/Scale	Score	ITPCn7a Executive %	ITPCn7b User %
1 *(Very Low)*	5	1.28	2.55
2 *(Low)*	4	5.11	11.49
3 *(Average)*	3	20.43	35.32
4 *(High)*	2	39.57	34.47
5 *(Very High)*	1	32.77	13.19
N/A		.85	2.98
Total		100.00	100.00
Mean		2.02	2.54

Table D26

ITPCn8 Organization Units Response Distribution and Statistics

Element	ITPCn8 Organization ($M = 3.71$)	
Factor/Scale	Score	ITPCn8 Units %
1 *(None)*	1	.43
2 *(1-2)*	2	16.17
3 *(3-5)*	3	31.91
4 *(5-7)*	4	14.04
5 *(More than 7)*	5	37.02
N/A		.43
Total		100.00

Table D27

ITPCn9 Contractors Units Response Distribution and Statistics

Element			ITPCn9 Contractors (*M* = 2.39)			
Factor/Scale	Score	ITPCn9a Contracts %	Factor/Scale	Score	ITPCn9b Familiar %	ITPCn9c Track Record %
1 *(None)*	1	16.60	1 *(Disagree Strongly)*	5	5.96	.43
2 *(1-2)*	2	36.17	2 *(Disagree)*	4	17.45	10.64
3 *(3-5)*	3	25.96	3 *(Neutral)*	3	12.77	20.85
4 *(5-7)*	4	8.09	4 *(Agree)*	2	29.36	34.89
5 *(More than 7)*	5	10.64	5 *(Agree Strongly)*	1	15.74	12.77
N/A		2.55	N/A		18.72	20.43
Total		100.00			100.00	100.00
Mean		2.59			2.61	2.39

Table D28

ITPS1 Project Completion Response Distribution and Statistics

Element	ITPS1 Completion (M = 4.32)		
Factor/Scale	Score	ITPS1a Completed %	ITPS1b Implemented %
1 *(Less than 25%)*	1	2.55	4.68
2 *(25-49%)*	2	3.40	4.26
3 *(50-74%)*	3	5.96	5.96
4 *(75-99%)*	4	27.23	31.49
5 *(100% or more)*	5	60.00	51.91
N/A		.85	1.70
Total		100.00	100.00
Mean		4.40	4.24

Table D29

ITPS2 Performance Baseline 1 Response Distribution and Statistics

Element	ITPS2 Performance Baseline 1 (*M* = 3.57)					
Factor/Scale	Score	ITPS2a Schedule %	ITPS2b Cost %	Factor/Scale	Score	ITPS2c Scope %
1 *(On or under plan)*	5	20.00	27.23	1 *(Less than 25%)*	1	8.09
2 *(Less than 20% over plan)*	4	26.81	25.11	2 *(25-49%)*	2	13.19
3 *(21-50% over plan)*	3	24.68	21.28	3 *(50-74%)*	3	8.09
4 *(51-100% over plan)*	2	15.32	9.79	4 *(75-99%)*	4	28.94
5 *(More than 100% over plan)*	1	10.21	6.81	5 *(100% or more)*	5	40.00
N/A		2.98	9.79	N/A		1.70
Total		100.00	100.00			100.00
Mean		3.32	3.62			3.81

Table D30

ITPS3 Performance Baseline n Response Distribution and Statistics

Element	ITPS3 Performance Baseline n (*M* = 3.87)					
Factor/Scale	Score	ITPS3a Schedule %	ITPS3b Cost %	Factor/Scale	Score	ITPS3c Scope %
1 *(On or under plan)*	5	33.62	35.32	1 *(Less than 25%)*	1	8.51
2 *(Less than 20% over plan)*	4	30.21	28.09	2 *(25-49%)*	2	8.09
3 *(21-50% over plan)*	3	14.04	13.62	3 *(50-74%)*	3	5.96
4 *(51-100% over plan)*	2	10.64	6.38	4 *(75-99%)*	4	26.38
5 *(More than 100% over plan)*	1	8.51	5.96	5 *(100% or more)*	5	48.09
N/A		2.98	10.64	N/A		2.98
Total		100.00	100.00			100.00
Mean		3.72	3.90			4.00