Exploratory Study of Risk Maturity Impact on Construction Project Outcomes

by

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ABSTRACT

The construction industry has accepted the uncertainty that is included with every project that is initiated. Because of the existing uncertainty, best practices with risk management are commonly recommended and educated to industry participants. However, the current status of the construction industry's ability to manage risk was found to be limited, unstructured, and inadequate. Furthermore, many barriers block organizations from implementing and improving risk management practices. A significant barrier with improving risk management methods is the lack of evidence that clearly demonstrates the need to improve risk management practices. Logical explanations of the benefits of risk management doesn't provide the necessary justification or motivation needed for many organizations to dedicate resources towards improving risk management.

Nevertheless, some organizations understand the importance of risk management practices and have begun to measure their risk maturity in order to identify weaknesses and improve risk management practices. Risk maturity measures the organization's ability and perceptions towards risk management. It is possible that many of the barriers to improving risk management would not exist if increased risk maturity was found to have a positive correlation with successful project performance.

The comprehensive hypothesis of the research is that increased risk maturity improves project performance. An exploratory study was conducted on data collected to identify measurable benefits with risk management. Quantitative and qualitative data was collected on 266 construction projects over a seven year period. Multiple statistical analyses were performed on the data and found a positive correlations between risk maturity and project performance. A positive correlations was found between customer satisfaction and contractors risk maturity. Additional findings from the recorded data included the increased ability to predict risks during construction projects within an organization. These findings provide clear reasoning for organizations to devote additional resources in which improve their risk management practices.

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CHAPTER 1

INTRODUCTION

Introduction

Recent surveys support the notion that the construction industry suffers from an inconsistent delivery of satisfactory performance. Responses from 557 members of the National Institute of Governmental Purchasing (NIGP) and the Institute of Supply Management (ISM) show that, among all goods and services purchased, construction contracts are perceived as having the greatest overall occurrence of problems (Davison & Sebastian, 2009a), and, as being the most likely to experience problematic consequences (Davison & Sebastian, 2009b). The problematic nature of the industry creates a necessity to manage and minimize risk consistently and effectively. Risk management methods have been found to improve project performance, customer satisfaction, and contractor productivity. However, various barriers in the industry impede the adoption and development of risk management practices within construction organizations. Additionally, owners often lack the capability, knowledge, and time to incorporate risk management methods in which potential vendors or suppliers are required to follow.

Barriers to Risk Management

Within the project management field the researcher found five recent studies that identified the major barriers in adopting and developing risk management methods. On review of the five articles, each article identified various barriers and conducted studies to identify the magnitude of the barrier. Table 1.1 presents the barriers identified in the studies with the rankings from greatest deterrence to least, a score of one representing the barrier which was found to be the largest deterrence to risk management. Table 1.1 provides a comprehensive view of the major barriers construction organization face with implementing and developing risk management efforts.

Table 1.1.

Barriers to Risk Management in Ranked order of Magnitude

Rank	Barrier	Tang et al. (2007)	Hlaing et al. (2008)	Tummala (1997)	Ho & Pike (1991)	Uher & Toakley (1999)	**Average**
1	Lack of: familiarity; understanding; knowledge; proficiency; expertise; and/or training	2	2	4	1	1	2.00
2	Lack of time	-	1	5	3	-	3.00
3	Lack of accuracy or validity of risk assessment (estimating and assessment of risk probability)	6	-	1	2	4	3.25
4	Lack of irrefutable: benefits; usefulness	4	3	-	5	2	3.50
5	Human Organization resistance	3	5	3	4	-	3.75
6	Lack of formal risk management system for project life-cycle	1	6	2	6	-	3.75
7	Ignorance	5	-	-	-	3	4.00
8	Lack of Money, Implementation cost	-	4	6	8	-	6.00
9	Lack of Top Management Support	-	-	7	7	5	6.33
10	Lack of Computing resources	-	-	8	9	-	8.50

It has been expressed that the attention, and subsequent expectations, put on risk management is predominantly based upon theoretical and anecdotal validity (Galway, 2004; Hillson, 2009; Hillson, 1999; Hillson, 1998; Williams, 1995). It seems fair to assume that if a rigorous body of work provided irrefutable evidence in support of the theorized project risk management benefits, more risk management: training would exist; time would be allotted; incentives would be created; reliable information/data would be collected; money would be provided; and, integration would take place. Such a chain reaction would logically lead to the minimization or elimination of these barriers.

The lack of irrefutable benefits does not necessarily exist due to a lack of effort in pursuing empirical evidence. The following studies are among the limited and, evidently, insufficient pool that presented findings in support of the notion that risk management correlates with project success. Research conducted by the Construction Industry Institute (CII) Pre-Project Planning Research Team shows that risk management is the driving force for pre-project planning (CII, 1995), where 'pre-project planning' is defined as: the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project. A number of research endeavors have shown a correlation between said pre-project planning and project success (in terms of cost and schedule performance) (Dumont et al., 1997; Gibson et al., 2006; Griffith et al., 1999; Wang, 2002).

Elkingston and Smallman (2002) identified a strong link between the amount of risk management undertaken in a project and the level of project success, and that the earlier risk management was used in a project, the higher its level of success, which reflects the findings of Shen (1997) and Thompson and Perry (1992). Raz and Michael (2001) discovered organizations who manage their projects more efficiently and more effectively tend to attach more value to risk analysis tools and tools that provide structure and discipline to the risk management effort. Tummala et al. (1997) found the majority of survey respondents agreed that risk management is particularly useful for providing insight into the project decisions, and increasing the chance of the project's success.

According to Hillson (2009), the reason the studies noted in the previous paragraph do not constitute an irrefutably robust body of work, and the reason such a body of work may never exist, is: since risk is, by definition, uncertain and may never happen, it is difficult to know the effect of any particular risk management effort on the outcome.

Research Problem

The built environment has accepted the uncertainty that is included with every project that is initiated: encountering risk with project objectives is inevitable. Because of the existing uncertainty, best practices with risk management are commonly recommended and educated to industry participants. The current status of the construction industry's ability to manage risks on projects was found to be very limited, unstructured, and inadequate. Furthermore, many barriers block capital project and facility organizations from implementing and improving risk management practices. Included in the participants of the industry are many capital owners whom are responsible for large infrastructures that include multiple buildings.

A significant barrier which owners face in improving risk management methods is the lack of evidence showing a clear benefit to dedicate additional resources to risk management. The lack of evidence is due to the difficulty of measuring and capturing the benefit that risk management practices provide on events that may or may not occur. Too many uncontrollable variables exist within construction projects to apply an accepted scientific test that can provide evidence of the benefits of risk management. Logical explanations of the benefits of risk management do not provide the necessary justification or motivation needed for many organizations to dedicate resources towards improving project risk management.

Because of the lack of easily justified benefits of risk management, adoption and improvement to organizations risk management practices is reliant on the risk maturity level of individual organizations. Risk maturity has been coined to measure an organization's ability and perception towards risk management, including the organizations: top managements perception with risk management; culture related to risk management; ability to identify risk; ability to analyze risk; and development of a standardized risk management process. It is possible that organizational risk maturity would increase and many of the barriers to implementing risk management would not exist if the benefits of risk management were found to have a positive correlation with successful project performance.

Research Objective

The research presented provides an analysis of the quantitative and qualitative benefits found on 266 construction projects over a seven year period. The comprehensive hypothesis of the research is that measured benefits from the implementation of risk management practices can be reasonable estimated for capital owners using quantitative and qualitative data collected on from the seven year case study. The purpose of the research was to provide a case study that explored the implementation of risk management in a capital organization. From the case study the research analyzed two research questions that included independent hypotheses.

1. *Question one – do the risk characteristics have an impact on the frequency and occurrence of risks during construction projects, the independent hypotheses from the first question are:*
    a. it is hypothesized that there are differences between the frequency and occurrence in the various risk types;
    b. it is hypothesized that there are differences between the frequency and occurrence in the various magnitude of impact the risk had on the project cost;
    c. and, it is hypothesized that there are differences between the frequency and occurrence in the various magnitude of impact the risk had on the project schedule.
2. *Question two – does the risk maturity of the contractors impact their project performance, the independent hypotheses from the second question are:*

a. it is hypothesized that there is a correlation between the contractors' risk maturity average and their win percentage;
b. and, it is hypothesized that there is a correlation between the contractors' risk maturity and the customers satisfaction ratings.

Research Scope

The uniqueness and complexity of construction projects have been found to be contributing factors to the unsatisfactory level of performance found in the build environment (Williams 1999; Huemann et al 2007; Dikmen et al. 2008; Hillson, 2009). Both the uniqueness and complexity of construction projects contribute to the high level of uncertainty found within projects, often defined as project risk. The uncertainty found within capital development projects is the reason that risk management is considered to be such a critical task with project management (PMI, 2008; ICE et al, 2005). The ability to manage risk often depends on the experience and expertise of the project manager, but organizations have the ability to capture risk information to help their project teams manage risk. Identifying and understanding the risks an organizations faces with construction projects is required for effective project risk management (Hillson, 2003a).

Implementing performance metrics that capture the common risks that facilities encounter will allow organization to identify and understand the risks that management should be concerned with. The construction industry's inability to implement performance metrics within their organizations has been highlighted in past research

(Egan 1998; Lee et al, 2000; Kagioglou et al, 2001; Smith, 2001). Research has shown that the common on-time and on-budget metrics do not sufficiently represent the projects effectiveness (Love & Skitmore, 1996; Kaigioglou et al, 2001). Risk measurement often includes project risk registries but these metrics in the end only provide a long list of risks that provide little assistance to future risk management (Hillson, 2003a). Quantitative risk measurements that can capture risk information on numerous projects can provide greater identification and understanding of an organizations ability to manage risk.

In 2005, a capital program of one of the largest universities in the United States found itself without the risk information needed to improve risk management. The university implemented a simple metric system that collected risk management performance on all of their capital projects. The metric system captured risks on projects and identified areas which needed improvement with managing project risk. After seven years of capturing risk impacts the university was able to capture project performance on 266 capital projects. Over a seven year period data was collected on 266 construction projects at the University. The majority of the projects were renovation projects on the campuses typically seen with a facility management department or a capital program.

Summary of Dissertation

The comprehensive hypothesis of the research is that increased risk maturity improves project performance. An exploratory study was conducted on data collected to identify measurable benefits with risk management. Quantitative and qualitative data was collected on 266 construction projects over a seven year period. Multiple statistical analyses were performed on the data and found a positive correlations between risk maturity and project performance. A positive correlations was found between customer satisfaction and contractors risk maturity. Additional findings from the recorded data included the increased ability to predict risks during construction projects within an organization. These findings provide clear reasoning for organizations to devote additional resources in which improve their risk management practices.

CHAPTER 2

LITERATURE REVIEW

Introduction

Among the contributing factors that create risk with construction is the inherent uniqueness and complexity of the projects (Amos & Dent, 1997; Dikmen et al., 2008; Gidado, 1996; Hillson, 2009; Williams, 1999). Construction, being a project-oriented industry (Huemann et al., 2007), is comprised of individual temporary projects, where each: has a unique design; is built in a unique location; is completed by a unique group of participants (i.e. a grouping of firms and employees rarely repeated on subsequent projects); has unique objectives, resources, and constraints; and, is executed during a unique period of time.

Compounding the uncertainty due to uniqueness of construction projects is the continual increase in complexity, size, and scope of the built environment (Dikmen et al., 2008; Gidado, 1996; Hillson, 2009; Williams, 1999). Tuman explained:

> One aspect of the future is obvious: all new undertakings will be accomplished in an increasingly complex technical, economic, political, and social environment. Thus project management must learn to deal with a much broader range of issues, requirements and problems in directing their projects to successful conclusions.

> Certainly, project management in every field will be called upon to address complexities and risks beyond anything experienced in the past.
>
> Tuman, 1986

The development of modern engineering principles, sophisticated construction practices, and new building and materials technologies has produced a host of specialized design disciplines and construction trades unknown prior to the 20th century. These modern disciplines, systems, equipment, and materials foster significant increases in the complexity, size, and scope of the built environment (Bruner, 2007; Hinchey, 1999; Williams, 1999; Zavadskas et al., 2010).

Increased technological complexity and specialization have resulted in increased fragmentation; more entities undertaking different parts of unique projects. Abi-Karam (2001) stated that the construction of a project is, at best, a fragmented process in a fragmented environment. On projects of even average complexity, there are typically tens of firms involved in the design, construction, and supplying of materials. In a cyclical manner, the fragmentation, stoked by technological complexity and specialization, increases organizational complexity, making it more difficult to coordinate and convey the sum of information necessary to successfully complete a project (Habison, 1985; Hinchey, 1999; Pich et al., 2002). Such technological and organizational complexity, under constantly unique scenarios (i.e. projects), generates significant risk (Akintoye & MacLeod, 1997; Williams, 1999; Zavadskas et al., 2010; Zhi, 1995; Zou et al., 2007).

When pieces of the ‘necessary sum of information’ are not acquired, coordinated, and/or conveyed, gaps in certainty are formed (i.e. epistemic or aleatoric uncertainties (Oakes, 1986)). The gaps are filled by project leaders’ decisions, which are based upon assumptions and/or ignorance (Aven & Steen, 2010; Hillson, 2009; Pender, 2001). These decisions, as place holders of certainty, are thus catalysts for risk (Dikmen et al., 2004; Kashiwagi, 2011; Pender, 2001). It is said that construction is likely exposed to more risk than any other industry sector (Flanagan & Norman, 1993; Thompson & Perry, 1992; Winch, 1987), and poor performance is said to often result from a failure to mitigating risks (CII, 1995; Hillson, 2009; Loosemoore et al., 2006; Royer, 2000). In other words, poor performance appears to often be the result of unmanaged risks inherent in the project-oriented nature of the construction industry.

Recent surveys support the notion that the construction industry suffers from an inconsistent delivery of satisfactory performance. Responses from 557 members of the National Institute of Governmental Purchasing (NIGP) and the Institute of Supply Management (ISM) show that, among all goods and services purchased, construction contracts are perceived as having the greatest overall occurrence of problems (Davison & Sebastian, 2009a), and, as being the most likely to experience problematic consequences (Davison & Sebastian, 2009b). The problematic nature of the industry creates a necessity to manage and minimize risk consistently and effectively. Risk management practices have been found to be a requirement within construction project management (Turner & Muller, 2003; Wood & Ellis, 2003; Dikmen, et al., 2008).

Managing project risk is considered to be a critical skill set for today's project managers, in as much as associations such as Project Management Institute (PMI) and the Association for Project Management (APM) consider project risk management as one of their core competencies. PMI's objective with project risk management states: "the objective is to increase the probability and impact of positive events, and decrease the probability and impacts of negative events in the project" (PMBOK, 2010). Similarly with this article, risk is defined as an uncertain event that, if occurs, will affect the achievement of the projects objectives either positively or negatively (Hillson, 2009; Williams, 1995). Hillson (2009) explains that risks during projects create both opportunities (positive risks) and threats (negative risks) to success. With the increased complexity, size, and scope of today's projects in the built environment managing these threats and opportunities proactively becomes a critical skill set (Dikmen et al., 2008).

Risk

There are numerous definitions of the word 'risk' (Hillson & Murray-Webster, 2006). Hillson (2009) outlined the variation among definitions utilized by many globally recognized professional institutes and national/international standards and guidelines. Simultaneously, he expressed the underlying similarity between them: an uncertainty that matters, particularly to the objectives. Hillson (2009; 2002) goes on to explain that the project management community is moving decisively toward including both positive (i.e. opportunity) and negative (i.e. threat) affects of 'uncertainty that matters' in the definition of risk. This is quickly verifiable by reading the definition of risk used in the Guide to the

Project Management Body Of Knowledge (PMBOK Guide) (PMI, 2010) and/or Risk Analysis & Management for Projects (RAMP) (ICE, et al., 2005). Amalgamating the discussions of Hillson (2009), Oakes (1986), Wharton (1992), and Williams (1995), the word ‘risk,’ herein, will refer to: an epistemically or aleatorically uncertain event that, if occurs, will affect the achievement of objectives (positively or negatively).

Risk Management

It is said that construction is likely exposed to more risk than any other industry sector (Flanagan & Norman, 1993) and poor performance has been contributed to the failure with risk management (Loosemoore et al., 2006; CII, 1995). The risky nature of construction has caused many researchers to focus on defining and improving risk management. The methods and objectives of risk management have been defined as the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact (Hubbard, 2009).

As a result of the construction industry’s high exposure to risk, and the expressed impact of neglecting risks, risk management has received much attention as an important component of successful project management (Akintoye & MacLeod, 1997; Baloi & Price, 2003; Cooke Davies, 2001; Crawford et al., 2006; Del Cano & de la Cruz, 2002; Dikmen, et al., 2008; Hillson, 1998; Muller & Turner, 2001; Raz & Michael, 2001; Themistocleous & Wearne, 2000; Tummala et al., 1997; Turner & Muller, 2003;

Williams, 1995; Wood & Ellis, 2003; Zou et al., 2007). Risk management has been defined as the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact (Hubbard, 2009).

As a result of the attention given to risk management, multiple formal/structured processes have been developed and included in national and international standards and guidelines (Del Cano & de la Cruz, 2002; Dikmen et al., 2004; Hillson, 2003b; Raz & Hillson, 2005). Although terminology differs between them, they tend to follow the same basic steps. A unified/generic risk management process based upon the multiple standards and guidelines can be found in Hillson (2009). To improve the ability to discover uncertainty, risk management literature includes planning activities, checklists, management models, and guides to facilitate the process; specific tools related to risk identification are: brainstorming activities, retrospective analysis, risk breakdown structures, scenario analysis, SWOT analysis, and expert interviews, (Hillson, 2003b; Kendrick, 2003). Although many resources are available to the industry, none of these tools alone can provide the expertise needed to effectively identify project risks early (Hillson, 2003b). Improvements in research related to risk identification can improve the predictability of risks during construction projects.

Risk Maturity

Risk maturity (RM) reflects the sophistication of an organization's understanding of its risk portfolio and how to manage those risks as well as the internal business continuity systems needed to cope with and recover from their eventuality (Zou et al, 2010). Hillson (1997) suggested that organizations wishing to implement a formal/structured approach to risk management need to treat the implementation itself as a project, requiring: clear objectives and success criteria; proper planning and resourcing; and, effective monitoring and control. To accomplish this, Hillson (1997) explained that organizations must be able to measure/benchmark their risk maturity (i.e. capability) using a generally accepted framework that: provides an objective assessment of current maturity levels; assists in setting realistic targets for improvement; and, can be used to measure progress towards targeted improvements. In the absence of such a framework, Hillson (1997) drew from the already established Capability Maturity Model (CMM) (developed by the Software Engineering Institute at Carnegie-Mellon University) to create the Risk Maturity Model (RMM).

Since the creation of the RMM, multiple maturity models have been developed for measuring organizations' risk management capability. Zou et al. (2010) compared eight risk maturity models, and three project management (PM) maturity models, to develop a risk maturity model specifically designed for construction organizations, called RM3.

RM3 consists of five attributes, designed to test different aspects of an organization's risk management capabilities against four levels of maturity. The five attributes include (Zou et al., 2010): 1) Management (people and leadership) capability in relation to risk; 2) Organizational risk culture; 3) Ability to identify risks; 4) Ability to analyze risks; and, 5) Development and application of standardized RM process. And, the four levels of maturity are (Zou et al., 2010); 1) Initial and/or Ad Hoc; 2) Repeatable; 3) Managed; and, 4) Optimized.

One of the four levels of maturity is identified for each of the five attributes, based on answers to questions that evaluate an organization's risk management capability. The model output provides the characteristics and overall maturity of a construction organization's risk management capability, against which an organization can benchmark current maturity levels, set target maturity levels, and measure progress toward targeted levels (Zou et al., 2010). For more details on RM3, see Zou et al. (2010).

Examples of the suitability and usefulness of risk maturity models can be found in: Del Cano and de la Cruz (2002); Hillson (1997); RMRDPC (2002); Hopkinson (2010); and, Zou et al. (2010). In their Project Uncertainty Management (PUMA) methodology - a hierarchically structured, flexible, and generic risk management process designed for construction projects - Del Cano and de la Cruz (2002) take the output of Hillson's (1997) RMM beyond an introspective organizational assessment to a source of information that, in addition to project size and complexity, helps define the level of risk management sophistication best suited for a particular construction project.

Status of Risk Management Maturity in the Construction Industry

To identify the status of risk management in the construction industry, a review was undertaken of literature that addressed trends and perceptions of risk management via surveys and/or interviews with industry professionals. Table 2.1 presents the most consistent findings, with respect to the status of risk management in the construction industry. Due to differing semantics across the multiple studies, the barriers presented in Table 2.1 were consolidated using the authors' best judgment, as can be seen by the multiple words used in the column headings. The risk management status of the industry was found to be inadequate, unstructured, and inconsistently used.

Table 2.1.

Status of Project Risk Management in the Construction Industry

	Status of risk management in the Construction Industry		
References	Low / Limited / Variable Usage	Unstructured / Unsophisticated	Inadequate / Ineffective / Incomplete
Akintoye & Macleod, 1997	×	×	×
Amos & Dent, 1997	×	×	×
Bajaj et al., 1997	×	×	×
Baker et al., 1999	×	--	×
Hlaing et al., 2008	×	×	--
Jackson et al., 1997	×	×	×
Kartam & Kartam, 2001	×	×	--
Kim & Bajaj, 2000	×	×	×
Liu et al., 2007	×	×	×
Low et al., 2009	×	×	×
Lyons & Skitmore, 2004	--	×	--
Shen, 1997	×	×	×
Simister, 1994	×	×	--
Tang et al., 2007	×	×	×

Thevendran & Mawdesley, 2004	×	×	×
Tummala et al., 1997	--	×	×
Uher & Toakley, 1999	×	--	×
Walewski & Gibson, 2003	×	×	×
Wood & Ellis, 2003	×	×	×

× Present in findings; -- Not present in findings

In addition to the studies outlined in Table 2.1, two pieces of literature were found that analyzed the construction industry's status of risk management via risk maturity models. Using Hillson's RMM to gauge the construction industry's level of risk maturity, Del Cano and de la Cruz (2002) found few organizations currently at Level 4; many organizations at either Levels 2 or 3, and a significant number at Level 1. Similarly, applying the RM3 to 60 Australian contractors, Zou et al. (2010) found the majority of contractors' risk maturity at Levels 2 and 3.

Risk Identification

A key task within risk management is identifying risks. Tools such as risk assessments, planning checklists, management models, and guides are available to improve the identification of uncertainty by the project stakeholders (Taroun, 2014; Batson, 2009; Gibson et al., 2006). Often these resources provide direction to identify the various types of risks that can be encountered during building projects but provide little guidance of when they will occur during the construction schedule.

Risk identification is often looked at the first process in risk management (Batson, 2009). Organizations have the ability to adopt various tools and processes to their identification methods, such as: checklists, brainstorming activities, diagramming techniques, retrospective analysis, risk breakdown structures, scenario analysis, SWOT analysis, interviews, surveys (Edwards et al, 2009; Kasap & Kaymak 2007; Hillson, 2003b; Kendrick, 2003). Risk identification should be performed throughout the project but in particularly before the notice to proceed. Risk identification prior to construction has been found to be optimal for project performance as it provides an opportunity for project stakeholders to align resources to minimize identified risks (Edwards et al, 2009; Gibson et al., 2006). Risk identification has also been found to improve cost estimating, Bajaj et al. (1997) found that when a risk identification process is performed it improves the accuracy of initial project estimates.

As mentioned above, one of the five attributes of an organization's RM is the ability to identify risks. Organizations looking to develop RM must improve their ability to identify project related risks. To assess the risk identification attribute the RM3 assess five aspects of the contractors: 1) do they identify risks consistently from project to project; 2) do they have a systematic identification method; 3) do they communicate identified risks to project participants; 4) is the firms risk identification method revised and reevaluated throughout the project process; and finally, 5) are the actual project risks compared against the initially identified risks (Zou et al., 2010). Once identified, a risk response will provide proactive solutions for risk mitigation.

Risk Management Plan

A risk analysis provides prioritization of the identified risks by the likelihood that they occur and their impact to project objectives such as time and cost. Organizations with high RM can provide a risk management plan (RMP) that provides effective solutions for the critical risks with high likelihood and impact. Solutions include various risk allocation methods that have been established within the project management industry (PMBOK, 2010), which include: negative risk allocation methods (avoidance, transfer, mitigation, and acceptance); and positive risk allocation methods (exploit, share, enhance, and accept). Deciding the effective method for each risk is usually at the discretion of the contractors. Akintoye & MacLeod (1997) found that contractors do not heavily favor one specific risk allocation method and that each contractor treats risk allocation differently. Being able to select and communicate the correct risk allocation method for each identified risk is second nature to an organization with optimized RM, according to Zou et al (2010). Risk plans that clearly communicate project participants' action items designate accountability with the risk allocation method. The following section presents a quantitative study that correlates risk management plans with customer satisfaction.

Project Risk Characteristics

Chapman and Ward (2007) highlighted the benefit to risk management by developing a more comprehensive and consistent method for risk identification. Researchers have defined risk categories by their nature, the agitator of the risk, and by the magnitude of impact. The nature of risks commonly includes categories such as: financial, strategic, operational, project, and hazard (AIRMIC & IRM, 2002; Chapman, 2001; Shen et al., 2001). A 2007 study (Zou et al.) identified key risks associated with construction projects, such as: tight project schedule, design variations, inadequate site information, inaccurate cost estimates, unavailability of managers and skilled laborers, low management competency of subcontractors, government interference, and price inflation.

Agitators or parties responsible for creating risk in construction projects are clients, designers, contractors, subcontractors/suppliers, government agencies (Zou et al., 2007; Perry & Hayes, 1985). Flanagan and Norman (1993) characterized risk by the magnitude of the impact to the project cost or schedule. A comprehensive and consistent method for categorizing risk has not been established due to the fragmentation within the research. The categories of risk that will be used and looked at in this paper will include the nature of the risks, the parties responsible, and the magnitude of impact to the project cost and schedule.

Risk Distribution in Building Projects

As risks are uncertain events, they are experienced throughout the project life cycle, unknown risks are not identified until additional information is discovered (Hillson, 2009). An extensive review of the literature was performed and found a gap in research related to the frequency and timing of risks during projects. Risk distribution in this paper is defined as the frequency and timing of risk events during the project life cycle.

Processes define when and how often risk management should be performed throughout the project (PMBOK, 2010), but little information is available to when certain risks occur. Zou (2007) identified the lack of research related to discovering risks throughout the project life cycle. A 2010 study identified the importance to understand the frequency of change orders in construction projects and what characteristics impact the frequency (Anastasopoulos et al.). However, there is a clear distinction between change orders and project risks, mainly risks deal with uncertain events, where change orders include events that have actual project impact. Understanding risk distribution could provide greater insight when project stakeholders discover information necessary to identify risks. The objective of this paper is to identify if the characteristics of risks have an impact on the distribution of risks in the construction phase.

Challenges with Implementing Metrics

Performance measurements are described as "quantifiable, simple, and understandable measures that can be used to compare and improve performance" (Pitcher, 2010). Pitt and Tucker (2008) explained the three reasons for measurements as: 1) to ensure the achievement of goals and objectives; 2) to evaluate, control, and improve procedures and processes; and 3) to compare and review the performance of different organizations, teams, and individuals. Two limitations are often seen with performance metrics in construction: first, metrics are retrospective, continuous performance metrics are necessary for them to be meaningful to the current market (Halachmi, 2005; Busco et al, 2006); and second, comparable benchmarks are often unavailable to contrast company performance, competitors reluctance to release proprietary information forces organizations to place benchmarks from past metrics or individual goals (Kaplan and Norton, 1992). The typical short term data of on-time or on-budget percentage provides little assistance to gauge performance of companies over a period of time (Love & Holt, 2000; Chapman et al, 1991).

Implementing metrics into an organization commonly requires a shift in the culture of the organization. According to Zaire (1996) there are six reasons that measurement systems fail when implemented, they are: 1) inability to define the operation process; 2) inability to relate the process to acceptable performance; 3) apprehension of misrepresenting performance; 4) apprehension of poor performance; 5) misinterpreting the measurements; and 6) collecting the wrong or unnecessary metrics. The psychological stimulus involved with implementing metrics has also been found to impact the results of temporary measurements. Mayo's (1949) research summarized that worker productivity increases with the psychological stimulus of being shown individual attention, feeling involved, and being made to feel important. Mayo stated that "Employees are more productive because the employees know they are being studied". Creating a measured environment alone can motivate employees to perform better for a period of time, but for continuous improvement, measurements must be implemented and managed efficiently within the organization (Halachmi, 2005).

The implementation of metrics into construction organizations has been found to be difficult. A 2008 extensive review of more than 4,500 articles on performance measurements within the build environment found the industries inability to utilize metrics effectively. The study found only 42 articles in which organizations implemented metrics and only 16 of the studies found improvements from the performance information (Egbu et al, 2008). The author's own literature review of numerous research papers found no methodologies that can be used by a construction organization to develop a performance measurement system that can capture multiple project data. Strategic planning is required to ensure that the common challenges are minimized when implementing metrics into an organization. To implement metrics Love and Skidmore (1996) focuses on six areas that need attention to achieve effective performance measurement systems:

1. develop an organization strategic plan with goals that have been established and agreed upon;
2. include both financial and nonfinancial business measures;
3. understand how benchmarks will be provided for comparative measurements;
4. clearly understand the organizations laws that govern the organizations behavior both within the organization and the industry;
5. present the results of the measurements consistently to develop a established workplace to encourage consistent reactions to the metrics;
6. and, have the full support of the leadership, driving the metric system from top to bottom while fostering a sense of belonging and responsibility among the work staff to the results.

Measuring Risk Management

Risk and project risk management has been heavily researched and has been found to be advantageous to project management. Project risk is often defined as an uncertain event that will impact project objectives if it occurs. Many researchers define risk as both negative and positive events, often describing negative risks as threats and positive risks as opportunities (Hillson & Murray-Webster, 2007). The combination of the discussion of Hillson (2009), Project Management Institute (2008), Williams (1995), Wharton (1992), and Oakes (1986) the word 'risk' in this paper refers to any uncertain event that, if occurs, will affect the achievement of the initial objective of the project contract (positively or negatively). Focusing on minimizing threats and optimizing opportunities will increase the success of construction projects.

As a result of the construction industry's high exposure to risk, and the expressed impact of neglecting risks, risk management has received much attention as an important component of successful project management (Hillson, 2009; Project Management Institute, 2008; Dikmen, et al., 2008). As a result of the attention given to risk management, multiple formal/structured project risk management processes have been developed and included in national and international standards and guidelines (Dikmen et al., 2008; Raz & Hillson, 2005). Although terminology differs between them, they tend to follow the same basic steps. A 2007(Aloini et al) review of various risk management methods identifies the most common phases found in risk management: 1) risk management analysis; 2) risk identification; 3) risk analysis; 4) risk evaluation; 5) risk treatment; 6) monitoring and review; and 7) communication and consulting. Project risk management is a proactive approach of minimizing both cost increases and schedule delays on individual projects.

Even with risk management processes in place, it is ambitious to believe that all risks will be identified and minimized. But capturing metrics of project team's performance with managing and minimizing risks on various projects can identify the areas that need improvement. As explained above, metrics must be strategically implemented to provide effective information. Kendrick (2009) suggested that risk metrics should be: 1) easy to implement; 2) agreed upon by all stake holders; 3) established to assure that they cannot be manipulated; and 4) not be used to punish employees. The following sections present an adoption of risk management measurements within an organization.

CHAPTER 3

CAPITAL PROGRAM CASE STUDY

Introduction

In 2005, the capital program at the University of Minnesota was unable to explain why projects were constantly over budget and over schedule. Stakeholders did not have measurements to inform them why their construction and renovation projects on the two main campuses were underperforming. The Capital Planning and Project Management (CPPM) department at the University of Minnesota is responsible for construction on the two main campuses. CPPM consists of a director, senior project managers, project managers, and support level staff that are responsible to ensure that all construction projects on campus are delivered effectively.

Without a comprehensive metric system collecting project impacts on all projects, information was gathered through perception and opinion alone, this consequentially left management skeptical of contractor’s performance. CPPM looked for ways in which they could begin capturing project risk management metrics to better understand performance and what was impacting projects. During 2005, CPPM began implementing metrics on the performance of construction and renovation projects on its campus (Sullivan et al, 2007). The following sections review the methodology that was used to implement risk measurement at the university and the results found from their measurements.

Weekly Risk Report

To capture the individual project metrics, CPPM required that all vendor project managers maintained a weekly report of all events that would potentially impact their individual projects. This report was referred to as the "Weekly Risk Report" (WRR). The development of the WRR has been described in further detail in past research (Sullivan et al, 2006) but, the main purposes of the WRR are:

1. provide basic project information;
2. track the project schedule;
3. track the cost of the project;
4. track any potential risks that occurred on the project;
5. track who and what caused the risk;
6. track the plan to manage and minimize the risk;
7. track if the risk actually impacted the cost or schedule;
8. track the deviation of the risks that impacted the project (cost and schedule increases);
9. assign a level of project severity for the executives;
10. capture the client's satisfaction ratings of contractor's ability to manage risk.

The university started implementing the WRR on select construction projects in 2005. The researchers educated both the CPPM and contractor project managers on the purpose and the methodology of the WRR. Contractors were responsible for the WRR and were educated to submit the report every Friday to all project stakeholders. CPPM project managers were responsible to ensure the validity of the information in each weekly report.

During the first year the WRR was introduced to eight projects to ensure adaptability of the WRR. After the first year the number of WRR's used on construction projects increased annually. The WRR was found to be so effective that in the year 2008 the university required that the report be used on all of their construction projects. By the year 2011, 266 weekly risk reports had been implemented on construction projects at the university. The year to year comparison of the number of WRR collected on projects at the university can be seen in Table 3.1. The majority of the projects were renovation projects on the campuses typically seen with a facility management department or a capital program. However, the 266 projects also included new construction of new buildings on the campuses. The average project cost of the projects with a WRR was 915,676 US dollars.

Table 3.1.

Year to Year Comparison of Projects Captured by WRR

Criteria	Overall	2005	2006	2007	2008	2009	2010	2011
Number of Projects	266	8	28	38	67	63	27	35
Awarded Cost (in Millions)	$243.57	$3.07	$8.43	$7.93	$20.25	$93.48	$28.45	$81.96

The intent of the report is for the contractor to identify potential risks and provide solutions to minimize the risks. Each risk that occurred on the project was labeled with a category responsible for the reason the risk occurred. These twelve categories were broken down into the party responsible for the risk and the general reasons why the risk occurred. These twelve categories were created through CPPM's instinct of the common project impacts that they had previously experience on their campus projects, they were:

1. CLIENT IMPACT - Scope Change / Decision
2. CPPM IMPACT - Codes / Permits
3. CPPM IMPACT - Contract / Payment
4. CPPM IMPACT - Energy Management
5. CPPM IMPACT - Hazardous / Health & Safety
6. CPPM IMPACT - Network / Telecom
7. CPPM IMPACT - Other
8. CONTRACTOR IMPACT - General Issues
9. CONTRACTOR IMPACT - Oversight of Design
10. CONTRACTOR IMPACT - Sub/Supplier Issues
11. DESIGN IMPACT - Error / Omission in Design
12. UNFORESEEN IMPACT

If a potential risk was not minimized and the project schedule was either delayed or a cost change occurred, the WRR was updated with the correct data. The project client representative was responsible to assure that the WRR contained the correct risk management information. The client representative also provided quantitative feedback on the WRR for the contractor's abilities to manage and minimize each risk. These client satisfaction evaluations were averaged and provided a final rating for the contractor's risk management performance on the project. On completion of the project the WRR summarized the risks that actually impacted the project cost or schedule. This information captured in the WRR was easily transferable to an executive level metric system.

Directors Report

The information in the WRR was transferred monthly to an executive level report called the "Director Report". Figure 3.1 depicts how the WRR's for the individual projects were captured into the Directors Report.

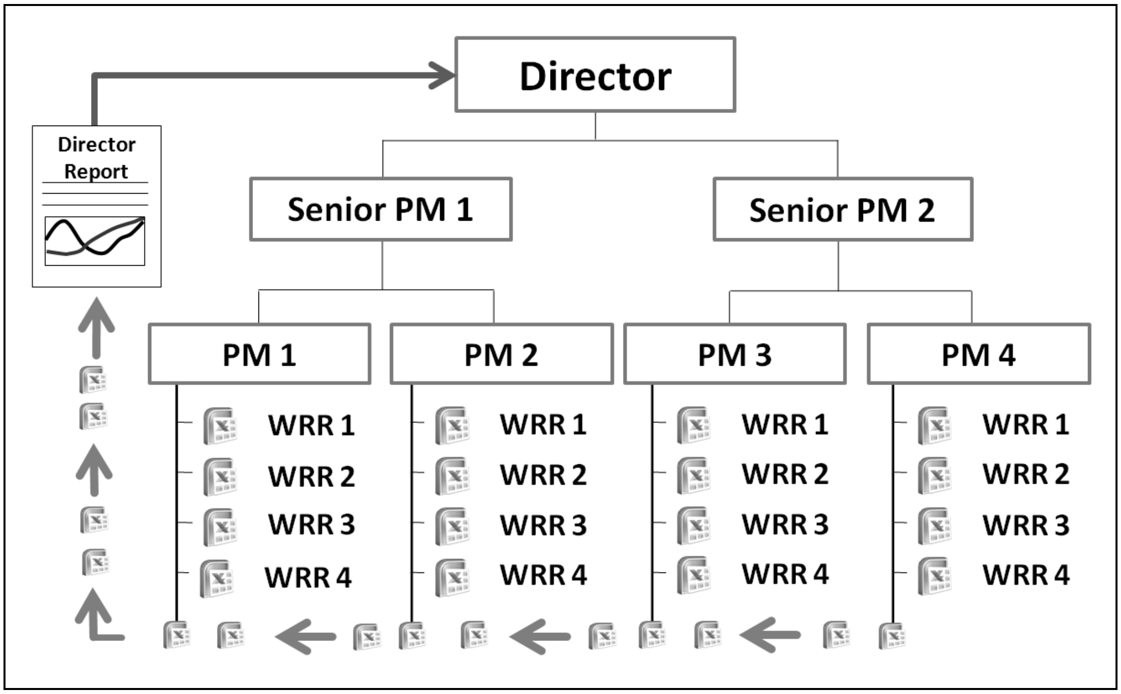

Figure 3.1. Directors Report Collecting Individual Project Metrics

The information collected from the WRR's was transferred to the Directors Report and formulated into comprehensible tables. The information was provided to management monthly to provide accurate project performance and indicated areas in which improvement was needed to manage risk on projects. The Director Report contains eight different analyses:

1. <u>Executive</u> - an overview of all the completed and ongoing projects performed on campus.
2. <u>Senior PM</u> – a breakdown of the project performance for the individual senior project managers.
3. <u>PM</u> – a breakdown of the project performance for the individual project managers.

4. Risk Impacts – a breakdown of all the risks and their impacts to the projects.
5. Vendors – performance metrics on individual contractors who've worked at the university.
6. Top 10 Risky Projects – the top ten projects in progress that have the greatest impacts on cost or schedule.
7. Close Out –the overall close out evaluations of the projects with the satisfaction of the client and the performance of the vendor.
8. Year to Year – a breakdown of annual project performance.

For this research the authors focused mainly on the information collected in the "Risk Impacts" analysis. The authors will present the information collected in the analysis in the next section and then discuss the researcher's observations and discussion from the information in the ensuing section.

Analysis of Cost Impacts

The risk impact analysis in the Director Report provides a detailed report of the risks that impacted projects at the university throughout the 2005 and 2011 period. The breakdown of the cost impacts for the 266 projects is found in Table 3.2; overall the campus projects experienced 7.79 million dollars of cost increases. But overall the cost increases of $7,796,350 represented only a 3.2 percent increase to the total amount awarded ($243.57 Million) for these projects. The majority (56.6 percent) of the cost impacts came from the clients of CPPM. Unforeseen cost increase accounted for 18.7 percent and design issues accounted for 9.1 percent. Overall the Capital Planning and Project Management department accounted for 15.4 percent of the change orders. Contractors only accounted for 0.3 percent of all project cost increases.

Table 3.2.

Cost Impacts during 2005-2011 (in US Dollars)

Category	Total Amount	%
CLIENT IMPACT - Scope Change / Decision	$4,410,736	56.57%
UNFORESEEN IMPACT	$1,458,065	18.70%
DESIGN IMPACT - Error / Omission in Design	$709,950	9.11%
CPPM IMPACT - Codes / Permits	$510,708	6.55%
CPPM IMPACT - Other	$487,889	6.26%
CPPM IMPACT - Energy Management	$87,470	1.12%
CPPM IMPACT - Hazardous / Health & Safety	$56,840	0.73%
CPPM IMPACT - Contract / Payment	$36,377	0.47%
CPPM IMPACT - Network / Telecom	$17,878	0.23%
CONTRACTOR IMPACT - Oversight of Design	$12,728	0.16%
CONTRACTOR IMPACT - General Issues	$11,699	0.15%
CONTRACTOR IMPACT - Sub/Supplier Issues	-$3,990	-0.05%
ALL COST IMPACTS	$7,796,350	100%

Analysis of Schedule Impacts

The WRR identified the risks that created the greatest percentages of the schedule delays on the construction projects, they can be found on Table 3.3. The total number of days that were awarded to the 266 projects was 28,393 days. Overall the projects were delayed by 13,873 days which represented an overall delay rate of 48.9 percent. Frequent scope changes from the client created 37.79 percent of the project delays. Impacts related to the

CPPM group were the next biggest cause of delays as they created 36 percent of the delays on the projects. Designers were responsible for little under 11 percent of the delays and unforeseen risks were just below 10 percent. Contractor created risks combined accounted for 5.9 percent of the delays.

Table 3.3.

Schedule Impacts during 2005-2011 (in days)

Category	Total Amount	%
CLIENT IMPACT - Scope Change / Decision	5243	37.79%
CPPM IMPACT - Other	3297	23.77%
DESIGN IMPACT - Error / Omission in Design	1506	10.86%
UNFORESEEN IMPACT	1362	9.82%
CPPM IMPACT - Codes / Permits	1072	7.73%
CONTRACTOR IMPACT - Sub/Supplier Issues	707	5.10%
CPPM IMPACT - Contract / Payment	294	2.12%
CPPM IMPACT - Hazardous / Health & Safety	140	1.01%
CONTRACTOR IMPACT - General Issues	98	0.71%
CPPM IMPACT - Energy Management	73	0.53%
CPPM IMPACT – Network / Telecom	73	0.53%
CONTRACTOR IMPACT - Oversight of Design	7	0.05%
ALL SCHEDULE IMPACTS (DAYS)	13872	100%

Analysis of Overall Risk Impacts

Table 3.4 shows the total number of risks that were seen on the 266 projects at the university. The table columns identify the total risks that were recorded on the WRR and the number and percent of risks that impacted both cost and schedule. In total 1506 risks were reported on the WRR’s over the seven years, 23 percent of these risks actually impacted the project cost and 24 percent of the risks actually impacted the project schedule.

Table 3.4.

Risks during 2005-2011

Category (in Order of Magnitude)	Total Number	Risks That Impacted Cost		Risks That Impacted Schedule	
		Number	Percent	Number	Percent
CLIENT IMPACT - Scope Change / Decision	585	103	18%	133	23%
UNFORESEEN IMPACT	273	57	21%	75	27%
DESIGN IMPACT - Error / Omission in Design	190	43	23%	60	32%
CPPM IMPACT - Codes / Permits	128	38	30%	42	33%
CPPM IMPACT - Other	102	36	35%	19	19%
CONTRACTOR IMPACT - Sub/Supplier Issues	91	34	37%	2	2%
CONTRACTOR IMPACT - General Issues	47	8	17%	2	4%
CPPM IMPACT - Contract / Payment	32	13	41%	4	13%
CPPM IMPACT - Hazardous / Health & Safety	22	9	41%	8	36%
CPPM IMPACT - Energy Management	18	6	33%	5	28%
CONTRACTOR IMPACT - Oversight of Design	9	2	22%	2	22%
CPPM IMPACT - Network / Telecom	9	3	33%	6	67%
Total Number of Impacts	1506	352	23%	358	24%

Discussion of Cost Impacts

The top three cost impacts that were seen on the projects were risks that the contractors and the CPPM group had little ability to minimize. Client scope changes were the foremost reason that project costs were increased after the contract had been signed with the contractors, representing 56.57 percent of the cost impacts. The “clients” were the various academic departments at the university and like other building owners are very susceptible to changing previous design decisions. Minimizing the risk of the clients changing scope is difficult for both CPPM and the contractor to do when they are not involved with the design. However, CPPM project managers were able to see from the metrics which clients regularly changed scope or decisions after the contractors was hired. This assisted the project managers so that they could be better prepared for the clients that frequently changed their minds and ensure that additional preplanning occurred. Proactive risk management should include steps for reducing these changes or decisions that owners initiate to ensure that projects are completed on time and on budget. Greater preplanning has been shown to improve the building development and decrease scope changes after the project has began (Gibson et al, 2006).

Unforeseen risks such as weather delays, geotechnical issues, or building unknowns were the second leading risk, and represented 18.7 percent of the impact to project cost increases. These risks were also found to be difficult to minimize from the contractors viewpoint, further analysis of these risk impacts can provide greater discussion of minimizing these unforeseen issues. A little over nine percent of the cost increases were due to omissions in the design as it was the third leading impact to the project cost. Issues with original designs continue to be a leading reason for cost increases as found in past research, Odeyinka & Larkins (2012) research found that the top risk occurrences to construction projects included design changes due to omissions.

The CPPM organization was responsible for the next six most common impacts to project cost and represented in total 15.36 percent of the total increases. Because of the size of the university the CPPM's responsibilities with each construction project are greater than the average client project management group. Difficulties acquiring codes and permits, requirements with energy management, health and safety, and contracts were leading areas that caused issues to the CPPM group. Again further analysis on the risks labeled as "CPPM - Others" would provide greater discussion on these risks. Coding and permits create the greatest risk to CPPM impacting the project costs, focusing on this project risk would create the most benefit to CPPM. CPPM has the ability to break down the risks for each CPPM project manager and highlight the main risks that have been involved on the individual PM's projects. They also have the ability to see their annual risk management performance broken down to create benchmarks for improvements.

Against the initial perception within CPPM, the cost impact created by the contractors was very low and only represented 0.26 percent of all project cost increases. The contractors on the university projects found that it was much easier to reduce their risk of impacting cost but it was more difficult to reduce the risk of the client, designer, and the CPPM group from creating risk to the project price.

Discussion of Schedule Impacts

Similar to the risks that increased the cost of the projects the main cause of schedule delays was seen to come from the client themselves. As Table 3.4 points out the majority of the delays came from the client and the client project management team. Frequent scope changes from the client created 37.79 percent of the project delays. The lack of efficient project programming and preplanning created these types of delays when owners realized the scope expectations were not correct. This is similar to past research that has identified the greatest impacts to the schedule are owner interference, delayed decisions, project financials, and ineffective project planning (Kumaraswamy & Chan, 1998).

In total the CPPM project responsibilities delayed the schedules by nearly 36 percent, similar to the change order increases the director of CPPM is better able to understand their departments impact on schedule delays. CPPM project managers also have the ability to see what the main delays are on their individual projects. This allows them to ensure they do not have similar delays in the future. However past research has cautioned that focusing on risks that have impacted past projects can create opportunities for new risks to occur on projects (Doloi et al, 2011), this warning is another recommendation that continuous risk management practices are critical.

Unforeseen and designer related risks accounted for over 20 percent of the schedule delays. Further analysis is needed to understand the causes of the unforeseen delays experienced on the project. Unlike the risks that impacted cost, contractors were not able to minimize the risks that created delays as effectively. When looking at the risks that delayed the projects the majority of the delays came from sub/supplier issues. Further analysis showed that the majority of these delays came from the contractor suppliers.

This risk can be minimized through efficient selection of material suppliers and including secondary plans to ensure materials are available accordingly.

Discussion of Overall Risk Impacts

Contractors were educated to report any risk that they potentially thought would impact the project. The contractor was responsible to prepare a plan to minimize the risk whether it was aligning resources to ensure decisions were timely executed or if was to lay out the technical steps to ensure constructability. The risks were updated weekly until the risk was mitigated, if the risk had an impact to the cost or schedule than the quantitative deviation from the plan was recorded on the WRR. The researchers found that the majority of the risks that could have potentially impacted the projects were mitigated to ensure that no schedule delays or cost increases occurred.

Overall 77 percent of the risks that were reported on the WRR's were minimized by the project stakeholders to ensure that they did not impact the cost of the project. Likewise, 76 percent of the risks reported were minimized effectively to not impact the schedule of the projects. Table 3.4 also presents the likely hood that the risks would impact the project if they were reported on the WRR. The risks that had the greatest chance of impacting the project dealt with the CPPM risk categories. This means that when the WRR identify that the CPPM group might impact the project then there was a good possibility that it would impact the project. The client has often been found to change their mind or change scope during the project which creates inefficiencies with the contractors initial planning. Because the WRR is developed by the contractors this meant that they were aware of the difficulties that were involved with getting the CPPM group to minimize the risks that they owned. Further research has looked at additional pre-planning activities to ensure the client has a complete understanding of the projects scope before construction begins.

CHAPTER 4

RISK ENCOUNTERS

Risk Encounter Study

During the years of 2005 through 2012, data was captured on capital projects within four different client departments of a large organization located in the United States. The data presented in this research is part of a wider study that involved introducing risk management tools within construction organizations (Perrenoud et al., 2014). Project risk registries captured extensive information of the risks that were experience during the construction phase of both new capital projects and renovations. In total, 229 Design-Bid-Build building projects were recorded during the seven year period. In total, 41 different contractors were awarded projects and the contractor's project manager was responsible to maintain and update the registry on a weekly basis. The client's project managers were responsible to ensure that the risk information was recorded accurately, consistently, and in a timely fashion for each of their projects. The risk entry was not finalized until both parties (contractor and client) agreed to the size, timing, and categorization of each risk. It can be assumed that additional risks with lesser probability and impact were experienced during the project but this research is limited only to the risks that concerned the project teams.

The registry captured and measured the initial project conditions assigned in the awarded contract, including among others: project type, beginning construction date, planned completion date, and the original contract cost. The intent of the registries was to capture information on all risks experienced during the projects, risk information that was required:

- Date entered – The date in which the risk was encountered.
- Risk category – Type of risk are identified and categorized.
- Risk details – Detailed information of the risk, what the plan was to mitigate the risk, individual(s) responsible to mitigate the risk, risk impact assessment, and weekly updates to the status of the risk and the plan to mitigate the risk.
- Planned resolution date – The planned date that the risk would be resolved.
- Actual date resolved – The actual date that the risk was resolved
- Impact to overall project duration – The resulting impact of the risk to the project schedule (in number of days)
- Impact to overall project cost – The resulting impact of the risk to the project cost.
- The client PM satisfaction rating – The client's project managers level of satisfaction with the contractor's performance related to the risk.

The above data for items five through eight could be updated each week based upon any new available information. Once a risk was closed out it was finalized to its impact within the project schedule or processed change order, or both. The data collected on the risk registries were transferred into one database for estimating statistical models. Table

4.1 presents a summary of the 229 projects. The average size of the project was $344,969 USD, which is consistent with past literatures definition of small projects (Liang et al., 2005; Conley & Gregory, 1999). The average schedule was 87 calendar days or close to a three month period. Overall, the cost increase rate was eight percent and the overall delay rate was 39 percent during construction.

Table 4.1.

Summary of Projects with Cost and Schedule Impacts

	Count	Sum	Sum	%
Number of Projects	229			
Total Cost (USD)		$78,997,931		
Average Cost		$344,969		
Overall Cost Increase			$6,600,743	8.4%
Client Cost Increase			$4,882,129	6.2%
Designer Cost Increase			$658,707	0.8%
Contractor Cost Increase			$10,014	0.0%
Unforeseen Cost Increase			$1,049,893	1.3%
Total Schedule (In Days)		19923		
Average Schedule		87		
Overall Schedule Increase			7819	39.2%
Client Schedule Increases			5487	27.5%
Designer Schedule Increase			822	4.1%
Contractor Schedule Increase			744	3.7%
Unforeseen Schedule Increase			766	3.8%

Risk Distribution

To identify the risk distribution or the frequency of occurrence during the project schedules Risk Encounter (RE) was developed. As can be seen in Formula 1, RE is established by dividing the number of days between the beginning contract date (BCD) and when the risk was identified on the registry, or risk identification date (RID) by the number of days between the BCD and the original completion date (OCD).

$$(RE) = \frac{RID - BCD}{OCD - BCD} \tag{1}$$

During the projects, the contractors' encountered 1229 project risks, an average of 5.4 risks per project. Risks were identified from the initial date of commencement, throughout the original schedule, and beyond. Due to project delays risks were recorded well past the projects original completion date. Figure 4.1 presents the histogram of the risk identified in the projects, included in the figure is a polynomial trend line which shows the frequency of the risks during the schedule. The figure also includes a dashed vertical line which represents the projects' original completion dates (OCD) (drawn at 100 percent). The average risk was identified at .79 or at 79 percent of the original schedule. This histogram presents an interesting and unique presentation of project risk data. With this information, the timing of risks on this project data set can be easily seen and examined.

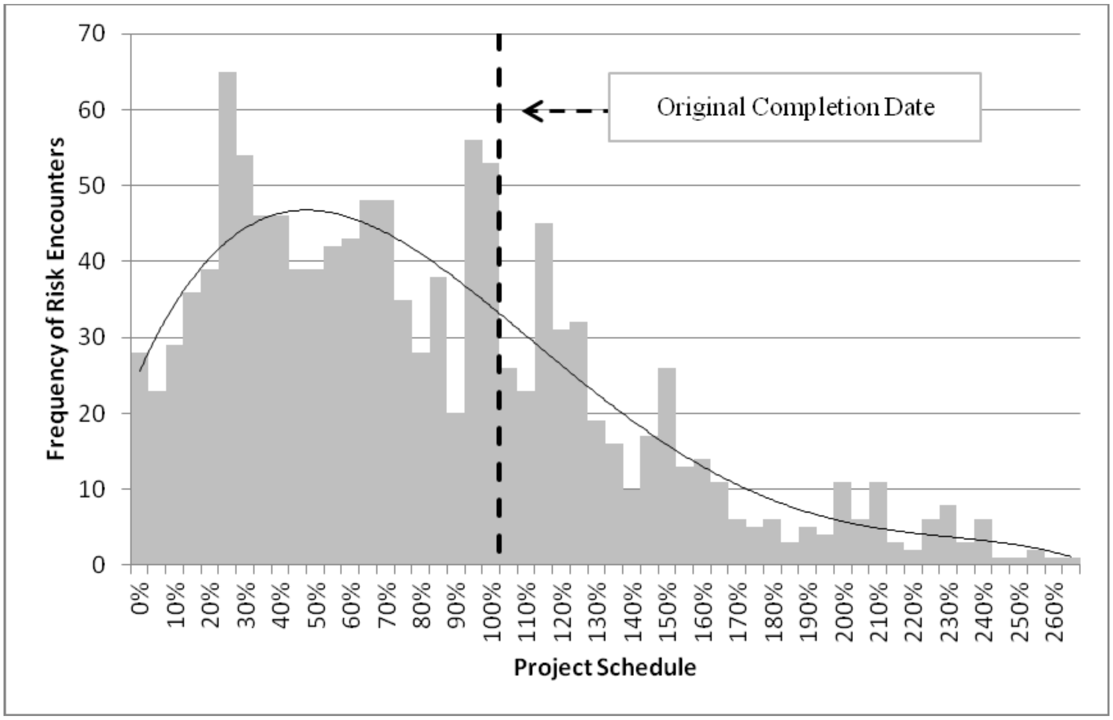

Figure 4.1. Building Project Risk Distribution

The histogram in Figure 4.1 presented four observational consequences. The first (1) observational consequence can be seen with the majority of the risk encounters occurring at the peak of the trend line between 20 – 70 percent of the schedule, 41 percent of the risks occurred during this peak. Similar to man hours on construction projects Risk Encounters experience a peak period during active phases of construction (Hanna et al., 2002). The second (2) observation was the distribution included multiple peaks during the construction project, peaks can be observed between 20-30, 60-75, 90-100, and 115-125 percent. These increases in occurrence of risk may indicate that there are common periods during the project schedule that contractors identify and communicate project risks to project stakeholders. An emerging question was if the different types or sources of project risks created the different peaks within the distribution.

The third (3) observation was regarding the RE increase during the last ten percent of the project schedule before OCD (second highest batch measured). From 90 to 100 percent of the project schedule, an average of 55 risks occurred per time period. This was much higher when compared against the time period between 50 to 90 percent that experienced only 38 risks per time period. The researchers speculated that the peak of risk encounters could possibly be attributed to two factors: contractors experienced or identified a high number of issues during the close out portion; and or the contractors delayed risk information from project stakeholders until the end of the project, hoping that they would be able to resolve the issue before impacting the project. Future research is needed to confirm the researcher's speculation. The fourth (4) observation consequence was that seventy percent of the risk encounters occurred before the OCD and thirty percent occurred after the OCD. The tail of the trend line in Figure 4.1 shows that projects experienced risks much later than originally schedule, the most extreme risk occurred 160 percent after the OCD. The authors found no other previous study that has tracked risks in regards to after the contractually designated end date. These observations generated further exploration of the impact that the different risk characteristics have on risk identification. This research is founded on the notion that a correlation can be made between unique risk characteristics and the distribution of risk encounters. By exploring the distribution of unique risks such as risk type and risk impact, the key correlations to the overall risk distribution can be discovered.

Project Risk by Type

The project teams identified nine different categories of risk during the projects, as can be seen in Table 4.2. The majority (43 percent) of the risks identified were client scope changes or decisions that impacted the project, which resulted in the largest impact to the project cost and schedule. On average the client scope changes were experience at .81 or at 81 percent of the original project schedule. The maximum occurrence of a client scope change was experienced at 2.64 or 264 percent of the original schedule, showing that the individual project experienced a large delay.

Table 4.2.

Descriptive Statistics of Project by Risk Type

	Risks		Cost Impact		Delay Impact		Risk Encounter				
Type	Count	Percent	Sum	Percent	Sum	Percent	Mean	Stand Error	Stand Dev	Min	Max
CLS	529	43.0%	$4,154,426	62.9%	3455	44.2%	0.81	0.02	0.54	0.00	2.64
CLC	120	9.8%	$553,879	8.4%	1160	14.8%	0.86	0.05	0.59	0.00	2.56
CLH	36	2.9%	$106,922	1.6%	180	2.3%	0.56	0.08	0.50	0.00	2.27
CLO	72	5.9%	$66,901	1.0%	692	8.9%	0.83	0.08	0.66	0.00	2.52
COS	84	6.8%	-$13,863	-0.2%	679	8.7%	0.99	0.06	0.59	0.00	2.40
COO	46	3.7%	$23,877	0.4%	65	0.8%	0.67	0.08	0.51	0.03	2.07
DEE	176	14.3%	$658,707	10.0%	822	10.5%	0.78	0.04	0.56	0.00	2.49
UNU	128	10.4%	$1,014,857	15.4%	554	7.1%	0.62	0.04	0.44	0.02	2.35
UNO	38	3.1%	$35,036	0.5%	212	2.7%	0.70	0.08	0.50	0.00	2.31
Total	1229		$6,600,743		7819						

CLS=Client Scope Change/Decision; CLC=Client Codes/Permits; CLH= Client Hazardous / Health & Safety; CLO= Client Other; COS= Contractor Sub/Supplier Issues; COO= Contractor Other; DEE= Error / Omission in Design; UNU= Unknown Existing Conditions; UNO= Other;

Figure 4.2, provides plots of the different risk types with the means of occurrence with their standard error. As can be seen in the figure there are differences between the means of when the different risk types occurred, the overall mean of .79. Risks related to hazardous materials had a mean of .56, signifying that they occurred closer to the beginning of the project schedules when compared to the rest. On the other side risk relating to subcontractors or supplier occurred towards the end of projects (mean of .99). Further statistical testing is performed below to identify any correlations between the means of the risk types and the overall distribution of risks.

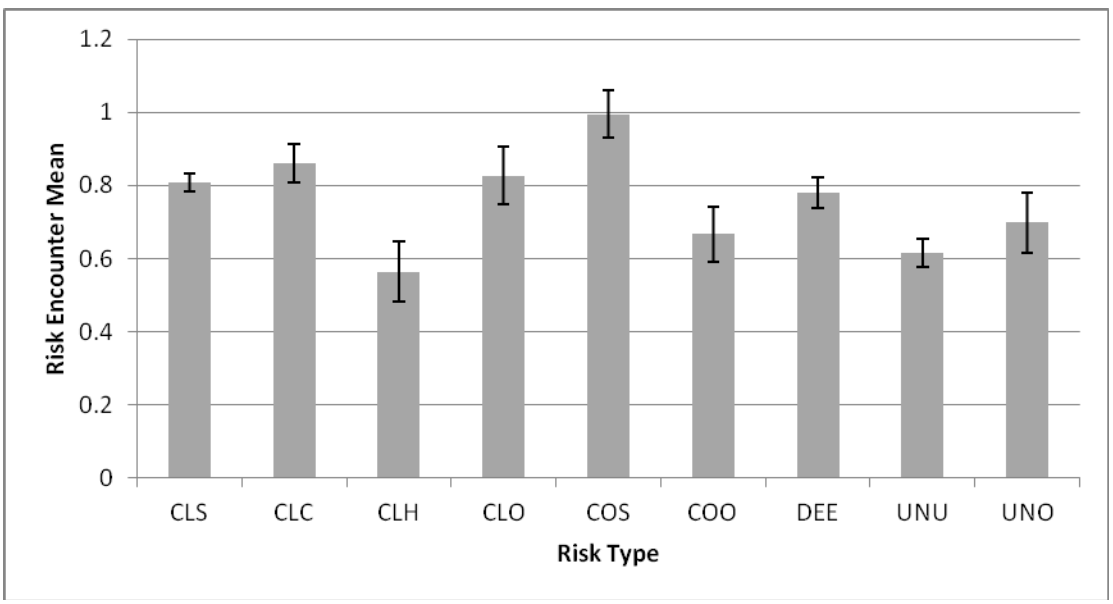

Figure 4.2. Risk Encounter Mean by Risk Type

Project Risk by Magnitude of Cost Impact

Uncertainties have varying levels of impact to project cost depending on their severity. This research looks at ten different levels of cost impact, which are presented in Table 4.3. As can be seen in the table, 33.4 percent of the risks recorded had zero impact to the project cost, 4.5 percent had a positive impact, which are seen as opportunities in risk research (Hillson, 2009). Risks with cost impacts below ten thousand dollars accounted for 81 percent of the risks that had negative cost impacts. However, risks impacts over ten thousand (19 percent) accounted for 73 percent of overall cost increases.

Table 4.3.

Descriptive Statistics of Project Risk by Magnitude of Cost Impact

		Risks		Cost Impact		Delay Impact		Risk Encounter				
#	Type	Count	%	Sum	%	Sum	%	Mean	Stand Error	Stand Dev	Min	Max
1	(<0)	55	4.5%	-$214,362	-3.2%	50	0.6%	0.75	0.07	0.50	0.00	2.22
2	0	410	33.4%	$0	0.0%	3157	40.4%	0.76	0.03	0.59	0.00	2.49
3	(1-999)	147	12.0%	$89,899	1.4%	257	3.3%	0.97	0.05	0.55	0.03	2.45
4	(1000-2499)	189	15.4%	$318,700	4.8%	597	7.6%	0.89	0.04	0.57	0.02	2.56
5	(2500-4999)	160	13.0%	$566,206	8.6%	660	8.4%	0.79	0.04	0.50	0.00	2.64
6	(5000-9999)	121	9.8%	$883,551	13.4%	831	10.6%	0.73	0.04	0.49	0.00	2.27
7	(10000-19999)	74	6.0%	$1,023,250	15.5%	420	5.4%	0.61	0.06	0.50	0.00	2.11
8	(20000-49999)	46	3.7%	$1,419,421	21.5%	1023	13.1%	0.62	0.06	0.43	0.07	2.04
9	(50000-99999)	17	1.4%	$1,203,559	18.2%	460	5.9%	0.66	0.10	0.42	0.00	1.44
10	(>100000)	10	0.8%	$1,310,520	19.9%	364	4.7%	0.59	0.13	0.41	0.00	1.26
	Total	1229		$6,600,743		7819						

Figure 4.3, presents the different means of the risks categorized by magnitude of impact to project cost. The mean of the risks that have negative impact to the project cost appear to trend down with size. The mean of the risks that have less impact than ten thousand dollars occur after or seventy percent of the project, while the mean of the larger risks occurs before .70. Future research can explore why the means of the more expensive risks occurs earlier in the project.

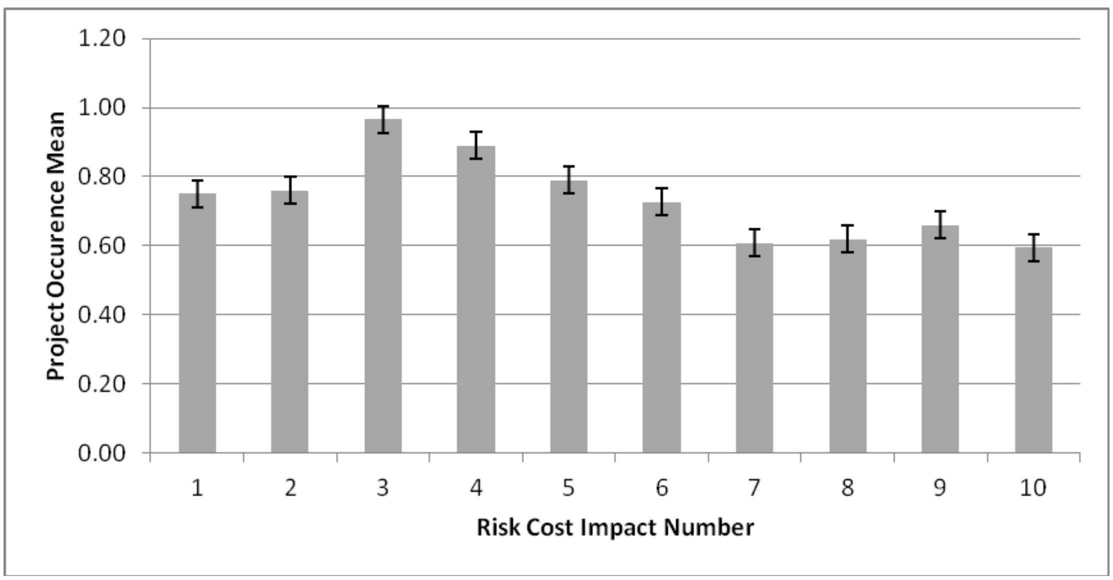

Figure 4.3. Risk Encounter Mean by Magnitude of Cost Impact

Project Risk by Magnitude of Schedule Impact

Perhaps the most interesting characteristic impact to the distribution of risks occurs with the different levels of impact to the project schedule. Table 4.4 presents the descriptive statistics of the risks categorized by the level of impact to schedule in calendar days.

Table 4.4.

Descriptive Statistics of Project Risk by Magnitude of Schedule Impact

		Risks		Cost Impact		Delay Impact		Risk Encounter				
#	Type	Count	%	Sum	%	Sum	%	Mean	Stand Error	Stand Dev	Min	Max
1	0	760	61.8%	$2,772,651	62.9%	0	44.2%	0.75	0.02	0.54	0.00	2.56
2	(1 - 4)	130	10.6%	$435,285	8.4%	292	14.8%	0.66	0.04	0.51	0.00	2.64
3	(5 - 9)	128	10.4%	$423,198	1.6%	805	2.3%	0.86	0.05	0.54	0.00	2.40
4	(10 - 19)	81	6.6%	$671,650	1.0%	1011	8.9%	0.86	0.06	0.58	0.00	2.49
5	(20 - 49)	98	8.0%	$1,462,099	-0.2%	2931	8.7%	0.99	0.06	0.57	0.00	2.40
6	(50 - 99)	23	1.9%	$631,919	0.4%	1480	0.8%	1.15	0.15	0.70	0.00	2.35
7	(>100)	9	0.7%	$203,942	10.0%	1300	10.5%	1.16	0.10	0.30	0.65	1.61
	Total	1229		$6,600,743		7819						

Figure 4.4 shows the RE means of the different level that the risk resulted on the project schedule. As can be seen with the risks that impacted the project schedule there is an upward trend with the risk occurrence means, showing that the risks with longer duration delays occurred closer to the end of the project. Statistical testing below describes the correlation between the two.

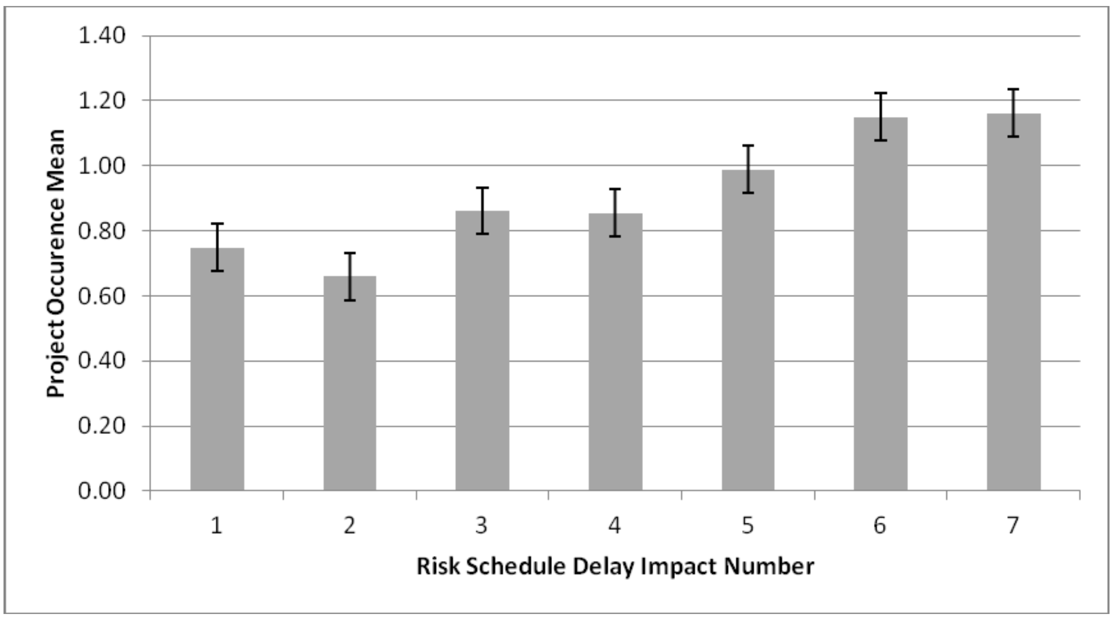

Figure 4.4. Risk Encounter Mean by Magnitude of Schedule Impact

Hypothesis Testing

The descriptive statistics of the different risk characteristics presented above provide a visual observation of the correlation between different characteristics of risk. Hypothesis testing was used to compare the means of the characteristics to the risk distribution. Two-factor analyses of variances (ANOVA) were performed to determine if the dependent variable, RE was affected by two or more factors. The independent variables being: risk type; cost impact; and schedule impact. The ANOVA is developed based on the assumption of the homogeneity of variances or that the variance within each the populations are equal (Maxwell & Delaney, 2004).

Levene's test for equality of variances was performed, because of the non-normality found within the data, RE data was rescaled and recoded into seven subintervals for homogeneity. These tests will address three research questions: (1) Are there differences between the means of the various risk types, (2) Are there differences between the means of the cost impact magnitude, and (3) Are there differences between the means of the schedule impact magnitude. The null hypothesis is that there is no difference between the means. Using SPSS(IBM Corp, 2012), three ANOVA tests were performed, the results are presented in Table 4.5.

Table 4.5.

ANOVA on Risk Occurrences during Project Schedule

Sources	Sum of Squares	*df*	Mean Square	*f*	Significance
Risk Type and Delay Impact					
Between Groups	3185.353	1	3185.353	848.259	0.000
Risk Type	53.790	8	6.724	1.791	0.075
Delay Impact	85.182	6	14.197	3.781	0.001
Within Groups	182.025	37	4.920	1.310	0.103
Total	24493.000	1229			
Risk Type and Cost Impact					

Between Groups	2133.990	1	2133.990	563.606	0.000
Cost Impact	97.124	9	10.792	2.850	0.003
Risk Type	61.515	8	7.689	2.031	0.040
Within Groups	172.560	50	3.451	0.911	0.650
Total	24493.000	1229			
Cost Impact and Delay Impact					
Between Groups	2625.072	1	2625.072	708.734	0.000
Cost Impact	98.904	9	10.989	2.967	0.000
Delay Impact	102.547	6	17.091	4.614	0.002
Within Groups	109.097	42	2.598	0.701	0.000
Total	24493.000	1229			

The results of the three ANOVA's performed showed no interaction between the two risk characteristics and the Risk Encounters. There was no statistically significant interaction between risk type and risk delay on Risk Encounters, $F(37,1177) = 1.310$, $p = .103$; neither between risk type and risk cost impact on RE, $F(50,1161) = 0.911$, $p = .650$; and neither between risk delay and risk cost impact on RE, $F(42,1171) = 0.701$, $p = .925$.

However, there was a statistically significant difference in Risk Encounters and the delay impact or the level of impact that the risk had on the schedule, $F(6, 1177) = 3.781$, $p = .001$. There also was statistically significant difference in Risk Encounters and the cost impact or the level of impact that the risk had on cost, $F(9,1161) = 2.850$, $p = .001$. This provides sufficient evidence to reject the null hypothesis in favor of the alternative hypothesis.

Delay Impact Analysis

A Spearman's rank-order correlation was run to assess the relationship between Risk Encounters and risk delay impact, see Formula 2.

$$r_s = 1 - \left(\frac{6\sum d^2}{(n^3 \quad n)}\right) \tag{2}$$

Preliminary analysis showed the relationship to be monotonic, as assessed by visual inspection of a scatter plot see Figure 4.5 and Post hoc multiple comparisons performed using the Ryan-Einot-Gabriel-Welsch F test for homogeneous subsets as seen in Table 4.6.

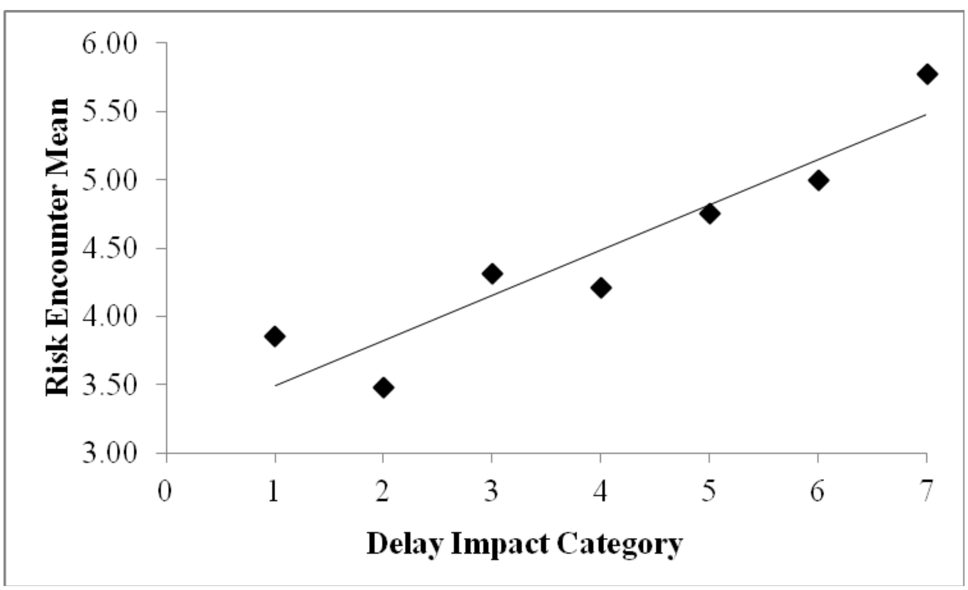

Figure 4.5. Delay Impact Mean Scatter Plot

There was a strong positive correlation between when risks occurred and the level of delay the risk had on the schedule, ρ (1177) = .127, $p < .01$. The risks with the largest delays occurred later during the project schedules. The regression equation was: predicted Risk Encounter = 0.5821+ 0.0839x (magnitude of delay impact) with the proportion of variance being equal to 0.89.

Table 4.6.

Delay Impact Post Hoc Ryan-Einot-Gabriel-Welsch F[a]

		Subset	
Delay Impact (In Days)	N	1	2
(1-4)	130	3.4846	
(0)	760	3.8526	
(10-19)	81	4.2099	4.2099
(5-9)	128		4.3125
(20-49)	98		4.7551
(50-99)	23		5.0000
(>100)	9		5.7778
Sig.		.059	.053

Cost Impact Analysis

A Spearman's rank-order correlation was run to assess the relationship between Risk Encounters and risk cost impact. There was a negative correlation between when risks occurred and the level of delay the risk had on the schedule, ρ (1161) = -.028. Post hoc multiple comparisons performed using the Ryan-Einot-Gabriel-Welsch F test for homogeneous subsets as seen in Table 4.7.

Table 4.7.

Cost Impact Post Hoc Test Ryan-Einot-Gabriel-Welsch F[a]

		Subset	
Cost Impact	N	1	2
(10000-19999)	74	3.3108	
(>100000)	10	3.4000	
(20000-49999)	46	3.4348	
(50000-99999)	17	3.7647	
(5000-9999)	121	3.7851	
(0)	410	3.8049	
(<0)	55	3.9818	3.9818
(2500-4999)	160	4.1125	4.1125
(1000-2499)	189		4.3757
(1-999)	147		4.6531
Sig.		.155	.116

The risks with the largest cost increase occurred earlier in the project. The regression equation was: predicted Risk Encounter = 4.3667- 0.0917x (magnitude of delay impact) with the proportion of variance being equal to 0.41. Additional analysis found that the larger risks occurred earlier in the project, see Figure 4.6.

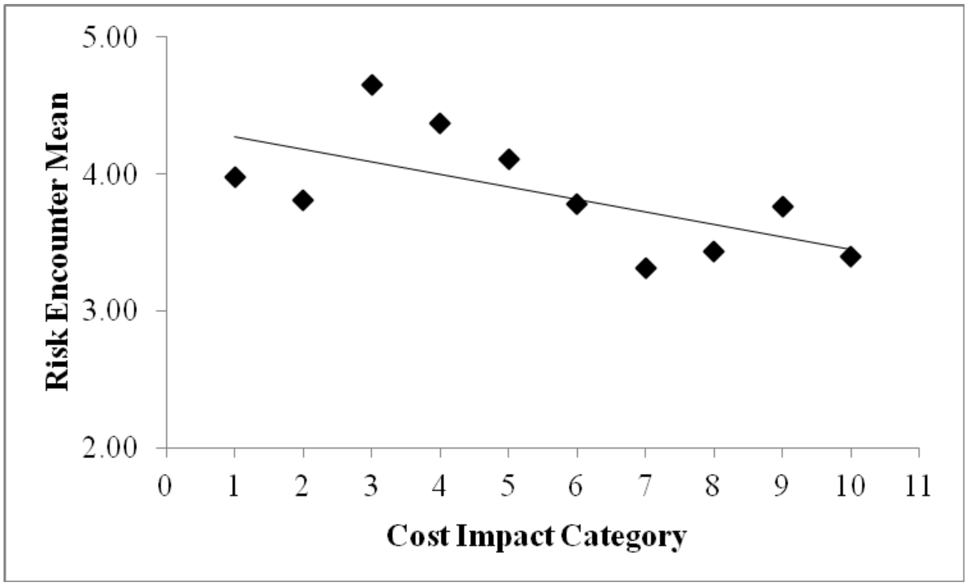

Figure 4.6. Cost Impact Mean Scatter Plot

CHAPTER 5

RISK MATURITY ANALYSIS ON PROJECT PERFORMANCE

Risk Maturity Study

To improve organizational RM and improve project performance a large University in the United States adopted a procurement process that included the evaluation of contractors RM with vendor selection (Perrenoud & Sullivan, 2014). In 2005, the Universities capital department adopted a value based procurement process that assigned weights to evaluation criteria, such as: cost, schedule duration, past performance ratings, value added options, and Risk Management Plan (RMP). The RMP provided an opportunity to demonstrate high RM with the universities projects. The request for proposal for each project included a two page template in which contractors identified project risks and developed risk allocation for the critical risks.

Contractors were educated on the risk assessment objective, but were not instructed on risk identification or risk allocation methods. A main requirement with the RMP was that contractors could not place any names or identifiable information on their assessment. This 'blind' plan method eliminated bias within the evaluation committee scores of the proponents. On submission of the contractors' proposals the evaluation committee members scored the contractors' RMP on a scale from one to ten, with ten representing high capability and one representing low capability. The evaluation committee on average consisted of four committee members from the university. The evaluation committee also scored the risk plans individually to eliminate scoring persuasion. The average of the scores from the committee members was figured into the final score. The RMP score on average was worth 30 percent of the scale used on the selection matrix. The objective of the value based procurement process was to select the contractors that scored the highest with all of the evaluation criteria.

Project Performance

A close out survey captured the quantitative performance of the awarded construction firms upon completion. The universities project manager involved with the construction project scored the contractors performance on a scale of one to ten, ten representing extremely satisfied and one representing extremely dissatisfied. The contractors' performance was evaluated with the following eight questions:

Q1. Ability to manage the project cost

Q2. Ability to maintain project schedule

Q3. Quality of workmanship

Q4. Professionalism and ability to manage

Q5. Close out process

Q6. Risk communication, explanation, and documentation

Q7. Ability to follow the users rules, regulations and requirements

Q8. Overall customer satisfaction

The close out questions collected subjective measurements key performance indicators that define project success (Chan & Chan, 2004; Chan et al., 2002), including cost, time, quality, and customer satisfaction. Question eight is a direct question assessing the overall customer satisfaction, which Torbica and Stroh (2001) believe is the most important measurement of project performance.

Hypothesis Testing

In total, twelve construction firms' that had close out survey scores submitted proposals across 178 projects at the university. During a three year period (2009-2012) 133 close out surveys were collected on the twelve contractors. Table 5.1 presents the number of RMPs that were evaluated by the client's evaluation committees, including their average score they received from the committees. The contractors win percentage reflects the percent of projects they were awarded divided by the number of projects they submitted proposals. Table 5.1 also presents the number of surveys collected for each contractor with the average score for each question.

The first objective of this research was to study the correlation between the contractors' RMP average score they received from the universities evaluation committee and their win percentage. The second objective looked at the correlation between the contractors' average RMP score and the questions from the close out survey. Below the researchers use a bivariate correlation analysis with SPSS (IBM Corp, 2012) to analyze the two research objectives.

Table 5.1.

Contractors Data Collection

	Risk Management Plan		Win %	Close Out Survey								
Contractor	N	Avg Score		N	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
CONTRACTOR 1	60	6.3	42%	18	9.3	9.5	9.5	9.6	8.9	9.6	9.8	9.5
CONTRACTOR 2	37	6.5	32%	9	9.4	9.7	9.8	9.8	9.9	9.7	9.6	9.7
CONTRACTOR 3	37	6.0	24%	7	10.0	9.6	9.6	10.0	9.2	9.9	9.9	9.7
CONTRACTOR 4	22	7.7	59%	13	9.7	9.5	9.8	9.7	8.9	9.4	9.8	9.5
CONTRACTOR 5	47	6.9	40%	12	10.0	9.8	9.8	10.0	9.7	9.8	9.6	9.8
CONTRACTOR 6	55	7.0	40%	21	9.4	9.5	9.8	9.9	9.5	9.7	9.9	9.6
CONTRACTOR 7	26	7.2	46%	11	9.4	9.5	9.5	9.5	8.6	9.8	9.4	9.3
CONTRACTOR 8	26	5.8	27%	7	9.9	10.0	9.9	9.5	9.0	9.6	9.9	9.7
CONTRACTOR 9	32	6.3	19%	6	8.9	9.3	9.3	9.7	9.5	9.2	9.3	9.3
CONTRACTOR 10	62	5.5	8%	5	8.8	7.9	8.5	7.8	8.0	8.1	9.0	8.1
CONTRACTOR 11	56	6.3	30%	15	9.2	8.7	9.3	9.1	8.9	8.8	9.0	9.0
CONTRACTOR 12	16	8.2	63%	9	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Total				133								

Analysis of Win Percentage

A Pearson's product-moment correlation was run to assess the relationship between the contractors' average RMP score and the close out survey scores. The magnitude of the Pearson correlation coefficient (r) determines the strength of the correlation: a high correlation is represented by an r-value greater than .5; a medium correlation is represented by an r-value between .3 and .5 (Cohen, 1988)

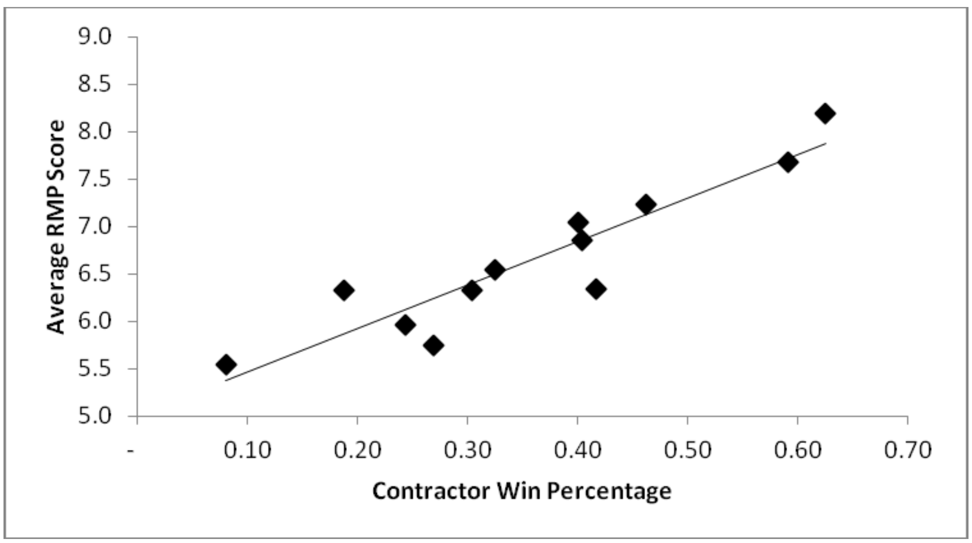

Figure 5.1. Win percentage to risk maturity relationship

As can be seen in Table 5.2, the studies first objective found a high correlation, r=.925, between the contractors win percentage and their average RMP score. Figure 5.1 presents the linear relationship. The coefficient of determination between these two variables was .85. Concluding that there was a high positive correlation between the contractors win percentage and their average RMP score, $r(10) = .925$, $p < .0005$, with the average RMP score explaining 85 percent of the variation in contractor win percentage.

Table 5.2.

Pearson Correlation between RMP and Contractor Win Percentage

Close Out Survey	Risk Management Plan Average Score		
	Pearson Correlation	Sig. (2-tailed)	N
Contractor Win Percentage	.925***	.000	12

***Correlation is significant at the 0.01 level.

Discussion of Win Percentage

The first objective of the study found a high positive correlation between win percentage and the contractor's ability to identify and prepare risks before projects began. The researcher assumes that the contractors RM reflects their average RMP score as they have demonstrated on numerous occasions they can identify and plan for specific project risks before the project begins. The value based selection process weighted the RMP on average 25 out of 100 points; with cost, schedule, duration, past performance ratings, and value added ideas as the remaining 75 points. Because the contractors with higher RMP scores had higher win percentages it is safe to say that contractors with higher RM will be more effective with estimating, scheduling, adding project value, and having better past performance. This correlates with other studies that have found successful companies involve project planning that incorporates risk management before actual construction begins (Hopkinson, 2011, Gibson et al., 2006, and Baja et al., 1997).

Analysis of Project Performance

A similar approach was conducted to analyze the correlation with the second objective that included studying the correlation with the RMP scores and the final close out evaluations of the client. A medium to high relationship was found between the contractors RMP scores and the eight questions included on the close out survey. The results of the Pearson's product-moment correlation can be found on Table 5.3.

Table 5.3.

Pearson Correlation between RMP and Customer Satisfaction

Close Out Survey		Risk Management Plan Average Score		
		Pearson Correlation	Sig. (1-tailed)	N
Q1	Ability to manage the project cost	.378	.113	12
Q2	Ability to maintain project schedule	.479*	.057	12
Q3	Quality of workmanship	.557**	.030	12
Q4	Professionalism and ability to manage	.524**	.040	12
Q5	Close out process	.473*	.060	12
Q6	Risk communication, explanation, and documentation	.513**	.044	12
Q7	Ability to follow the users rules, regulations and requirements	.430*	.081	12
Q8	Overall customer satisfaction	.522**	.041	12

**Correlation is significant at the 0.05 level.

*Correlation is significant at the 0.1 level.

As seen in Table 5.3, high correlations were found between the contractors RMP scores and four of the questions on the close out survey, in order of magnitude: Q3 – Quality of workmanship $r(11) = .557$, $p < .05$; Q4 – Professionalism and ability to manage $r(11) = .524$, $p < .05$; Q8 – Overall customer satisfaction $r(11) = .522$, $p < .05$; Q6 – Risk communication, explanation, and documentation $r(11) = .513$, $p < .05$. To further explore the collected data and validate earlier correlations, linear regression tests were conducted with the eight questions, Table 5.4 presents the summarized data.

Table 5.4.

Summarized results of the Linear Regression Testing

Ref	R	R Square	Adjusted R Square	Durbin-Watson	F	Sig.	t	Sig.	Unstandardized Coefficients		Standardized Coefficients
									B	SE	Beta
Q1	0.378	0.143	0.058	0.967	1.671	0.225	1.293	0.225	0.715	0.553	0.378
Q2	0.479	0.23	0.153	1.369	2.985	0.115	1.728	0.115	0.646	0.374	0.479
Q3	0.557	0.31	0.241	1.259	4.501	0.06	2.122	0.06	1.09	0.514	0.557
Q4	0.524	0.275	0.202	1.525	3.791	0.08	1.947	0.08	0.681	0.35	0.524
Q5	0.473	0.223	0.146	1.543	2.877	0.121	1.696	0.121	0.653	0.385	0.473
Q6	0.513	0.263	0.189	1.578	3.563	0.088	1.888	0.088	0.734	0.389	0.513
Q7	0.43	0.185	0.104	1.058	2.274	0.162	1.508	0.162	0.977	0.648	0.43
Q8	0.522	0.272	0.2	1.401	3.744	0.082	1.935	0.082	0.82	0.424	0.522

Discussion of Project Performance

The coefficient of determination between the quality of workmanship and the contractors average RMP score was .31. Concluding that there was a positive correlation between the quality of workmanship and their average RMP score, $r(11) = .557$, $p < .05$, with the average RMP score explaining 31 percent of the variation in quality of workmanship. Providing poor quality is both a contractual risk and a reputational risk, underperforming or providing an inferior product would not only risk the contractors ability to profit from project, but also impacts the client's sense of the contractors ability to provide quality construction. Some contractors may measure their performance by the client's approval of the final product, when quality issues are presented proactive solutions from contractors demonstrates their expertise and ability to manage quality risks.

The coefficient of determination between the professionalism and ability to manage and the contractors average RMP score was .28. Concluding that there was a positive correlation between the professionalism and ability to manage and their average RMP score, $r(11) = .524$, $p < .05$, with the average RMP score explaining 28 percent of the variation in professionalism and ability to manage. Due to the uncertainty in construction, professionalism within the construction industry can refer to a contractor's ability to provide service within a changing environment. Contractors that lack the ability to identify and mitigate threats will encounter more risks that are past the point of mitigation, in which case impacts project objectives.

The coefficient of determination between the overall customer satisfaction and the contractors average RMP score was .27. Concluding that there was a positive correlation between the overall customer satisfaction and their average RMP score, $r(11) = .522$, $p < .05$, with the average RMP score explaining 27 percent of the variation in overall customer satisfaction**.** The overall satisfaction rating is most likely the closest qualitative measurement provided by the client. This case study found that the majority of the project objective impacts came from externally driven risks, risks that the contractors had to manage with the assistance of a third party, externally driven risks include: client scope changes, design errors, suppliers, etc.(Perrenoud & Sullivan, 2013). It can be seen that risk management increases customer satisfaction, as the contractors with higher RM scored higher with the client's quantitative rating.

The coefficient of determination between the risk communication and the contractors average RMP score was .26. Concluding that there was a positive correlation between the risk communication and their average RMP score, $r(11) = .513$, $p < .05$, with the average RMP score explaining 26 percent of the variation in risk communication. Effective communication of risks throughout the project provides project transparency with project stakeholders. Risk transparency creates accountability for project stakeholders responsible to mitigate risk. Non-transparent projects that have experienced multiple project objective impacts will lower customer satisfaction, delays schedule, and cause tension between project stakeholders.

Cross Validation

The findings from above were cross examined by cross-tabulating the results of both the Pearson correlations and their linear regression, the results are presented in Table 5.5. This table shows the F values from linear regression ranked in descending order along with the correlation values from the Pearson correlations. It is observed that the linear regression analysis supports the results of the correlation tests.

Table 5.5.

Cross Validation with average RMP score as the dependent variable

Ref	Independent variables	Pearson Correlation	Linear Regression Results	
		r	F	Sig.
	Contractor Win Percentage	.925	58.89	0.000
Q3	Quality of workmanship	.557	4.501	0.060
Q4	Professionalism and ability to manage	.524	3.791	0.080
Q8	Overall customer satisfaction	.522	3.744	0.082
Q6	Risk communication, explanation, and documentation	.513	3.563	0.088
Q2	Ability to maintain project schedule	.479	2.985	0.115
Q5	Close out process	.473	2.877	0.121
Q7	Ability to follow the users rules, regulations and requirements	.430	2.274	0.162
Q1	Ability to manage the project cost	.378	1.671	0.225

CHAPTER 6

CONCLUSION

Introduction

Included with the many barriers of improving risk management practices, the construction industries risk management process were found to be limited, unstructured, and ineffective. An increased understanding of risk management benefits would raise the construction industries efforts towards developing an effective, structured and absolute risk management process. The objective of this dissertation was to capture the benefits identified during the process of increasing one organizations risk maturity on 266 construction projects across a seven year period. The following section will summarize the subsequent findings from the research.

University Case Study

Risk maturity has been coined by research as the measurement of an organizations perception and ability to manage risk. In 2005, the capital management department at the University of Minnesota began researching and implementing tools to increase their organizations risk maturity. Included in their risk maturity development was the introduction of the Weekly Risk Report (WRR) to their construction projects. The WRR captured information on risk management efforts on both ongoing and completed projects. The WRR was found to be a simple tool to implement on their construction projects. The WRR tool improved risk management communication by capturing risk mitigation plans, risk outcomes, and risk impact data. Risks are defined as uncertain events that may or may not impact projects objectives. The risk data provided transparency to the common issues that plagued project performance at the University. The consequential management actions from the collected data was included in the research. Highlighting the importance of clear project scopes and construction drawings the research found that the majority of the risk came from internal project stake holders. Changes in design or scope from the university's stakeholders accounted for 56.6 percent of the cost increases and 37.8 percent of the schedule delays. The remaining risks highlight areas in which the capital program at the university has a greater ability to manage risk impacts. The risks that were created by the internal capital program accounted for 15.4 percent of the cost increases and 36 percent of the schedule delays. The metrics provided individual risk information among the universities project managers which allowed management to align resources to improve performance. It also included valuable information on the contractors risk management abilities that worked on the universities campuses along with client satisfaction ratings.

Risk Encounters

The research investigated the frequency and occurrence of the risks during the construction projects. Figure 4.1 provides a clear visual representation of when risks were encountered during the construction projects. Three major observations were seen with the data: 1) the majority of the risks were encountered between 30-60 percent of the original schedule; 2) thirty percent of the risks were encountered after the original completion date; and 3) there were a number of peaks and valleys during the construction projects in which risks were encountered. The researcher examined the characteristics of the risks to determine if they had an impact on the frequency and occurrence of the risks.

Risk Encounter (RE) was defined as the period during the project schedule in which a risk was identified and communicated to the project team. The risk characteristics that were examined in this research are: risk type, cost impact, and delay impact. Analyses between REs and risk characteristics found correlations between the RE and the magnitude of schedule and cost impacts. Statistical testing, including Anova and Spearman Correlation coefficient tests were performed to validate the correlation between the REs and their characteristics.

The research identified a positive linear relationship between the magnitude of schedule delay and RE, concluding that as the magnitude of schedule delays increased, the risks were encountered later in the schedule. This is comparable to the common research that suggest that severe project impacts occur later in construction projects (Rybkowski et al., 2012; Hendrickson & Au, 1989). Future research can explain why project teams either delay the communication of large schedule delays or if they are not able to identify them until late.

Upon investigation of the magnitude of cost impact and REs a negative correlation was found between the two variables. Although it was non-linear the risks that had a greater impact to the project cost occurred towards the beginning of the project, risks with smaller cost impacts on average occurred later. Figure 4.6 presents the relationship between the cost impact characteristic and the REs.

Risk type was also correlated against RE but no correlations were found, however the RE mean was identified for each type of risks, identifying the average time during the schedule that certain risk types occur. Table 4.2 presents when the different types of risks occurred on average. The risk type that occurred later in projects dealt with subcontractor or supplier issues which occurred at 99 percent of the original schedule. The risks that had the greatest impact to project schedule were the client scope changes which occurred on average at 81 percent of the original schedule. The average risk encounter occurred at 79 percent of the original schedule.

Contractor's Risk Maturity Impact on Project Performance

Finally the research examined how contractors' risk maturity impacted customer satisfaction. The risk maturity of the proposing contractors was captured during procurement and analyzed against the final outcomes of the projects. Contractor performance was captured by the client project stakeholders with an eight question survey administered on project completion. Cross validation of Pearson coefficient correlations and linear regressions presented in Table 5.5 found a positive relationship between contractor RM and project performance.

Furthermore the contractor’s ability to win proposals was also found to be directly correlated to their RM. Increasing RM was found to impact the contractors’ ability to effectively schedule, estimate, and plan projects during pre-construction phases. This provides further definition to the importance of project planning that incorporates risk management before construction begins.

Conclusion

In conclusion, the research provided clear benefits that result from increased risk maturity within construction organizations. Contractors that had higher risk maturity enjoyed higher customer satisfaction after construction. This research also provides a methodology for organizations to adopt project risk metrics and become more aware of the common schedule delays and cost increases experienced within their project portfolio. The capital organization presented within this research was able to clearly understand how often their projects experience risk and the timing and frequency of different risk types.

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