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Applying Probabilistic Risk Analysis in Design and Construction

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APPLYING PROBABILISTIC RISK ANALYSIS IN
DESIGN AND CONSTRUCTION

By

CHRISTOPHER WILLIAM SENESI

B.S., Ohio Northern University, 2010

A thesis submitted to the
Faculty of the Graduate School of the
University of Colorado in partial fulfillment
of the requirement for the degree of
Masters of Science

Department of Civil, Environmental and Architectural Engineering

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APPROVAL

This thesis entitled:
Applying Probabilistic Risk Analysis in Design and Construction
written by Christopher William Senesi
has been approved for the Department of Civil, Environmental and Architectural Engineering

Dr. Amy Javernick-Will

Dr. Keith Molenaar

Dr. Matthew Hallowell

Date _____

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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ABSTRACT

Senesi, Christopher William (M.S., Civil, Environmental and Architectural Engineering)

Applying Probabilistic Risk Analysis in Design and Construction

Thesis directed by Assistant Professor Amy Javernick-Will and co-directed by Professor Keith Molenaar

Although probabilistic risk analysis methods, a component of project risk management, have been regularly available to designer and construction practitioners since the early 1990s, their use is not pervasive in the construction industry today. Using a multi-method analysis, including in-depth interviews and survey questionnaires, this research identified the benefits and barriers of employing probabilistic risk analysis with a focus on companies in the Construction Industry Institute (CII) and the Project Management Institute (PMI). The research identified benefits that include the ability to better manage project cost and schedule, the ability to better manage risks, the ability to make risks explicit, increased confidence in project decision making, and increased internal collaboration and discussion among the project team and organization. The research also uncovered several barriers that organizations face when implementing probabilistic risk analysis. These barriers include a lack of organizational support, a lack of policy and procedures, difficulty interpreting results, and a lack of technical expertise.

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TABLE OF CONTENTS

1.	INTRODUCTION.....	1
	a. Observed Problem.....	1
	b. Research Question & Method Overview.....	2
	c. Thesis Format.....	4
	d. References.....	5
2.	BENEFITS AND BARRIERS TO APPLYING PROBABILISTIC RISK ANALYSIS ON DESIGN AND CONSTRUCTION PROJECTS.....	7
	a. Abstract.....	7
	b. Keywords.....	8
	c. Introduction.....	8
	d. Current Use of Probabilistic Risk Analysis.....	9
	e. Research Method.....	11
	i. <i>Qualitative In-Depth Interviews</i>	11
	ii. <i>Validation Survey</i>	14
	f. Results.....	14
	i. <i>Benefits</i>	14
	ii. <i>Validation of Benefits</i>	19
	iii. <i>Barriers</i>	21
	iv. <i>Validation of Barriers</i>	24
	g. Discussion and Application.....	25
	h. Conclusion.....	29
	i. References.....	31
3.	CONCLUSION.....	33
	a. Theoretical Contributions.....	33
	b. Limitations & Future Research.....	36
4.	BIBLIOGRAPHY.....	39
5.	APPENDIX.....	41
	a. Organizational Questions.....	41
	b. Project Portfolio Questions.....	44
	c. Project Questions.....	47

LIST OF TABLES***Table***

1. Companies Selected for Interviews based on Attributes	12
2. Interview Results – <i>Benefits</i>	15
3. Validation Results – <i>Benefits</i>	20
4. Interview Results – <i>Barriers</i>	21
5. Validation Results – <i>Barriers</i>	25

LIST OF FIGURES

Figure

1. Gaps in Research & Research Question3

2. Overall Research Approach3

3. Theoretical Contributions33

4. Limitations & Future Research36

CHAPTER 1

INTRODUCTION

Observed Problem

For many years, the design and construction industry has struggled with the use of risk management, an important component of project management that deals with inherent uncertainty on projects. Proper use of risk management can be very beneficial for organizations, enhancing profitability and minimizing loss (Akintoye & MacLeod 1997; Flyvbjerg et. al. 2002; Zwikael & Ahn 2010), yet adequate and widespread implementation of risk management is not common across the industry (RMRDPC 2002). And, organizations that do use risk management typically only apply deterministic approaches to risk analysis. Deterministic approaches do not consider the uncertainty inherent in design and construction projects, nor do they explicitly address the potential risk. In contrast, probabilistic risk analysis is a method for analyzing project risk and uncertainty in cost, schedule, and scope, taking into account risk and opportunity events that cannot be adequately defined in the design or construction planning.

Probabilistic tools for identifying, assessing, and managing risk and uncertainty on construction projects are neither new nor unique to the construction industry (Mak & Picken 2000; CII 2010; Kangari & Riggs 1989). The use of probabilistic methods for the analysis of go/no-go capital investment decisions as well as the development of contingency in major construction projects emerged in the 1970's and 1980's (DOE 1991; Diekmann 1983). At this time, major government agencies, including the US Department of Energy (DOE) and the Federal Highway Administration (FHWA) started publishing guidelines and specifications relating to probabilistic risk analysis for their larger projects. Additionally, professional societies began publishing articles defining probabilistic methods and how organizations should handle

uncertainty in design and construction projects. For example, the Construction Industry Institute (CII) published one of its first probabilistic method articles in 1989, titled “Management of Project Risk and Uncertainty” (CII 2010).

In the last decade, there has been more focus and improvement to risk management, including risk analysis and probabilistic controls. Several industry organizations have written and published guidelines that specifically address risk management, encouraging design and construction firms to employ probabilistic risk analysis for their projects. These guidelines include “Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model” (AACE 2011), “Management of Project Risks and Uncertainties” (reprint from the 1989 version mentioned previously) (CII 2010), *Risk Management – Principles and Guidelines, ISO 31000* (ISO 2009), and *A Guide to the Project Management Body of Knowledge (PMBOK Guide)* (PMI 2000). Given these guidelines and the existence of probabilistic risk analysis for the last 30-40 years, the question is then why is probabilistic risk analysis still not being used more often and on a broader scale.

Research Question & Method Overview

Given that risk management is essential to minimizing losses and enhancing profitability (Flyvbjerg et. al. 2002; Zwikael & Ahn 2010; Akintoye & MacLeod 1997) and that widespread use of risk management is not prevalent (RMRDPC 2002, Zou et al. 2011), this research sought to identify the benefits of and barriers to using probabilistic risk analysis. Figure 1 illustrates this gap in literature and the corresponding research question.

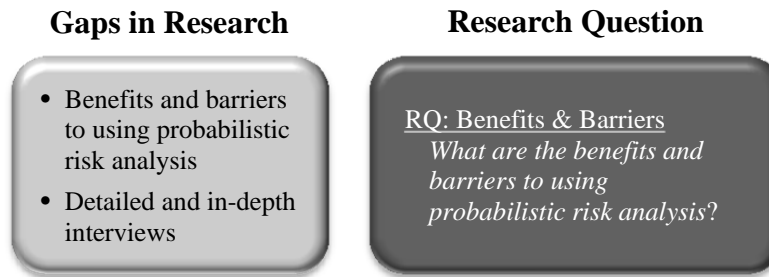


Figure 1: Gaps in Research & Research Question

In addition to the lack of studies on benefits and barriers to probabilistic risk analysis, there was minimal qualitative research, specifically in identifying the benefits and barriers. Therefore, the research employed both quantitative and qualitative methods for data collection and analysis in a phased, multi-method approach. Following a detailed literature review, the research was conducted in three phases that included a state-of-practice survey, in-depth interviews, and a validation survey. Figure 2 outlines this approach.

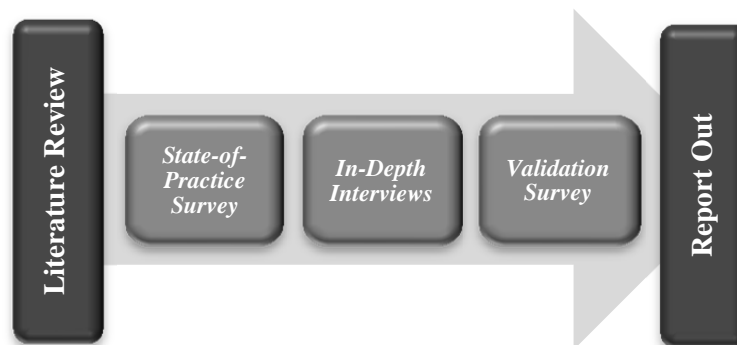


Figure 2: Overall Research Approach

An embedded unit of analysis, focused on individual responses within larger organizations, was used. The state-of-practice survey allowed the research team to determine the use of risk management approaches, particularly probabilistic risk analysis, in Construction Industry Institute (CII) and Project Management Institute (PMI) member companies based upon

employee responses. The survey also helped identify and benchmark organizations for in-depth interviews. Interviews were selected because it allows for “depth – detail, richness, and completeness” (Flyvbjerg, 2011, p314) of projects and organizations. In addition, it helps answer “what” and “why” questions, including *what* are the benefits and barriers to implementing probabilistic risk analysis and *why* organizations were using (or not using) probabilistic risk analysis approaches on their projects. The final phase of the research, the validation survey, enabled the research team to validate the findings from the literature review, the state-of-practice survey and interviews. This allowed greater generalization about the use of risk management and probabilistic controls in the construction industry.

Thesis Format

The questions and results presented in this thesis follow the “journal paper” format. Chapter 2 is a stand-alone paper that will be submitted to an academic journal. As such, the paper (chapter) contains its own abstract, introduction, points of departure, research method, results, conclusion and reference sections. Due to this format, some degree of overlap exists. In particular, the introductions, points of departure, and methodology overlap significantly with the introduction and conclusion chapter (Chapter 1 and 3, respectively).

The concluding chapter of this thesis summarizes the theoretical and practical contributions from this research and provides suggestions for future research. Finally, in addition to including references within each of the chapters, there is a complete bibliography at the end of the thesis.

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CHAPTER 2

BENEFITS AND BARRIERS TO APPLYING PROBABILISTIC RISK ANALYSIS ON DESIGN AND CONSTRUCTION PROJECTS

Abstract

Although probabilistic risk analysis methods have been available to designer and construction practitioners since the early 1990s, their use is not pervasive in the construction industry today. This research explores the benefits and barriers to the use of probabilistic methods to see why their use is not more prevalent. Using a multi-method analysis, including in-depth interviews and survey questionnaires, this research identified the benefits and barriers of employing probabilistic risk analysis with a focus on companies in the Construction Industry Institute (CII) and the Project Management Institute (PMI). The research identified benefits that include the ability to better manage project cost and schedule, the ability to better manage risks, the ability to make risks explicit, increased confidence in project decision making, and increased internal collaboration and discussion among the project team and organization. The research also uncovered several barriers that organizations face when implementing probabilistic risk analysis. These barriers include a lack of organizational support, a lack of policy and procedures, difficulty interpreting results, and a lack of technical expertise. Organizations can implement more formal project risk management approaches by focusing on sharing benefits and strategically overcoming the barriers by training employees, adopting processes and procedures for risk management, and regularly communicating the results of probabilistic analysis with project stakeholders.

Keywords

Project Risk Management, Risk Analysis, Probabilistic, Construction Management,

Introduction

In the design and construction industry, projects consist of a multitude of human, technical, and environmental factors coordinated by engineers and construction managers. These projects can be complex in nature and carry much uncertainty throughout the project lifecycle. In addition, nontechnical challenges, such as economic, societal, and political issues overshadow the engineering and construction complexities (Bruzelius et al. 1998; Flyvbjerg 1996; Flyvbjerg et al. 2002). These challenges frequently result in significant cost over-runs, schedule delays, and the misallocation of resources from risk-averse contracting strategies. While a risk-based mentality has become prevalent in the current social and business climate, and tools for identifying, assessing, and managing risk is neither new nor unique to the industry (Mak & Picken 2000; CII 2010; Kangari & Riggs 1989); the vast majority of the construction industry applies only a deterministic approach in project risk management. These deterministic tools do not consider the uncertainty inherent in engineering and construction projects, nor do they explicitly address the potential risk. In contrast, probabilistic controls are methods for managing project risk and uncertainty in cost, schedule, and scope, taking into account risk and opportunity events that cannot be adequately defined in the design or construction planning. These tools show promise for improving contract risk-allocation strategies and providing more informative project controls analysis.

The literature also indicates that although there are benefits to using probabilistic analysis over deterministic analysis (Akintoye & MacLeod 1997), there are many misperceptions of probabilistic analysis and most project managers do not understand the benefits clearly (Mak & Picken 2000). The obstacle, and consequently the scope of this research, is therefore to identify the benefits of employing probabilistic risk analysis and the barriers preventing its use.

Current Use of Probabilistic Risk Analysis

The design and construction industry has struggled with project risk management for more than 70 years. Generally, risk analysis is either ignored or done subjectively by simply adding a percentage contingency to cost and schedule estimates (Mak & Picken 2000). As a result, many major projects fail to meet cost targets and schedule deadlines, causing losses to all involved, including engineers, contractors, and owners. Persistent cost underestimation as well as schedule delays reflect poorly on the industry. One example of the poor handling of risk is evident in Flyvbjerg's et. al. (2002) study on large-scale transportation projects. The research found that project costs are underestimated in almost 9 out of 10 projects. Additionally, for a randomly selected project, the likelihood of actual costs being larger than estimated costs is 86 percent. The data also indicates that non-transportation related projects are just as likely, if not more likely, to underestimate project costs (Flyvbjerg et. al. 2002).

Further yet, although probabilistic tools have been refined, Flyvbjerg et. al. (2002) concluded that cost underestimation, an indirect cause of poor risk management, has been stagnant over time. Flyvbjerg et. al. (2002, p286) further state that "if techniques and skills for estimating and forecasting costs of transportation infrastructure projects have improved over time, this does not show in the data. No learning seems to take place in this important and highly

costly sector of public and private decision making.” This is not to say that a probabilistic approach to risk analysis will eliminate cost and schedule overruns, but it should provide managers a more rational basis on how to make decisions (Kangari & Riggs 1989; Molenaar 2005).

In the last decade, organizations have focused more on risk management, including probabilistic risk analysis. Probabilistic risk analysis involves the use of methods for managing project uncertainty in cost, scope, and schedule taking into account known or unknown events or conditions that cannot be defined adequately. The most common tools are driven by Monte Carlo analysis techniques for cost and schedule elements that are embedded in a comprehensive risk management approach. Deterministic risk analysis employs a similar process, but it uses only the expected value for risks (i.e., probability of risk occurrence multiplied by magnitude of risk occurrence) and it does not employ simulation techniques. Several industry organizations have written and published guidelines that specifically address risk management, encouraging design and construction firms to employ probabilistic risk analysis on their projects. These guidelines include “Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model.” (AACE 2011), “Management of Project Risks and Uncertainties” (CII 2010), *Risk Management – Principles and Guidelines, ISO 31000* (ISO 2009), and *A Guide to the Project Management Body of Knowledge (PMBOK Guide)* (PMI 2000). Given the existence of probabilistic risk analysis for over 30 years and guidelines written to encourage their use, the question is then why these probabilistic methods are not being used more often.

Given that risk management is essential to minimizing losses and enhancing profitability on construction projects (Akintoye & MacLeod 1997; Flyvbjerg et. al. 2002; Zwikael & Ahn 2010), organizations are beginning to recognize the increasing importance of risk analysis.

However, the engineering and construction industry uses few formal techniques of risk analysis and, in most cases, only basic non-probabilistic methods are used. Construction research, therefore, needs to address the benefits achieved from using probabilistic approaches if such techniques are to be of practical value to the design and construction industry (Akintoye & MacLeod 1997).

This research addresses these prior calls and gaps by first identifying and validating the benefits of using probabilistic approaches and then uncovering the barriers that must be surmounted to use probabilistic approaches for risk management. The research used a multi-method approach, including both survey questionnaires and in-depth interviews, to obtain a more holistic view of these benefits and barriers.

Research Method

The research employed both qualitative and quantitative methods for data collection and analysis in a phased, multi-method approach.

Qualitative In-Depth Interviews

To begin, the research team sent a questionnaire to members of the Construction Industry Institute (CII) and the Project Management Institute (PMI) Construction Industry Community of Practice. The questionnaire sent to these members was used to determine the current state-of-practice of project risk management and project controls in the engineering and construction industry – specifically, what approaches and tools organizations were using for risk management on their projects. We employed the questionnaire to help select organizations for further study where interviews could be conducted. We selected twelve organizations primarily because they

were implementing or in the process of implementing probabilistic risk analysis. One organization, although not implementing probabilistic risk analysis at the time of the study was determining use of the technique in the near future. By selecting only organizations that implemented or were looking to adopt probabilistic risk analysis, helped us ensure literal replication (Yin 2009), predicting that the benefit and barriers to probabilistic risk analysis would be similar across the organizations. We also ensured diversity amongst key attributes including both owners and contractors, those that work in the public or private sector, and those that completed diverse project types, including horizontal (e.g. roads, pipelines), vertical (e.g. building, stadiums), and process (e.g. refinery, manufacturing). The diversity amongst key attributes helped ensure theoretical replication by attending to key differences that may impact benefits and barriers from a cross comparison. Table 1 lists the organizations represented based upon these selected attributes with the number of interviewees in each organization.

Table 1: Companies Selected for Interviews based on Attributes

Company	Owner or Contractor		Public or Private		Type (Horz, Vert, or Process)			Number of Interviewees
	O	C	Pu	Pr	H	V	P	
1	X		X		X	X	X	4
2		X	X	X	X	X	X	3
3	X		X		X			4
4		X	X	X	X	X	X	5
5	X		X		X		X	4
6	X			X		X	X	4
7		X	X	X	X			3
8	X			X		X		3
9	X		X		X			5
10	X			X			X	1
11	X		X		X			6
12		X		X			X	5
TOTALS	8	4	8	7	8	5	7	47

Prior to the interviews, the interview scope was defined, including specific subtopics and key questions (Singleton & Straits, 2004). The interviews aimed to address questions of “what” and “why”: specifically *what* are the benefits and barriers to implementing probabilistic risk

analysis approaches on projects and *why* organizations were using (or not using) probabilistic risk analysis approaches on their projects. Each interview had specific objectives and data collection requirements. Furthermore, the interviewer sought answers and explanation to a variety of categories through semi-structured, open-ended questions. Three questionnaires were developed for different interviewees within the organization focusing on the enterprise, portfolio, and project level (see the appendix for questionnaires). To achieve internal validity, similar questions were asked across all interviews, to ensure that findings were consistent throughout the organization, that is, does a senior manager have similar views on the use of probabilistic risk analysis as compared to a project manager. To establish construct validity, the research team also collected documents from the organizations, helping to ensure similar results from multiple sources of data collection. Documents collected included policy and procedures, processes, reports, and forms, all relating to risk management and probabilistic risk analysis.

Interview transcriptions were collected and coded in the qualitative data analysis software, QSR NVivo Version 9. This ensured transparency and thoroughness of the interviews and added rigor to the qualitative analysis (Bazeley and Richards, 2000; Richards and Richards, 1991). After the data was uploaded into QSR NVivo, categories (or codes) were created for topics, themes, and concepts that emerged during the interviews. Initially, macro categories of benefits and barriers to probabilistic risk analysis were identified to ensure that our responses were coded. This coding scheme allowed the data to be filtered down to more manageable components for analysis. Subsequently, these macro categories were analyzed and further coded into subcategories of benefits and barriers. These were then analyzed and discussed with the research team in an iterative fashion, where detailed notes were taken and codes were checked to ensure consistency and reproducibility.

Validation Survey

After the interviews were completed and the interview data was analyzed, a final survey questionnaire was distributed to validate the findings through a larger sample. The questionnaire was distributed to the same directory as the initial state-of-practice survey, namely CII and PMI organizations. Ninety-three respondents, who represented 73 different organizations, responded to the questionnaire. These organizations included owners (39) and contractors (34) and represented four sectors including, infrastructure (18 organizations), heavy industrial (37 organizations), light industrial (14 organizations) and commercial building (25 organizations).

Results

In order to better understand the value of using probabilistic risk analysis as well as why organizations are not using a probabilistic approach to risk analysis, the results focus on both the benefits and barriers to adopting probabilistic risk analysis. The interviews allowed for open-ended discussion, which was valuable to collect a comprehensive list of benefits of and barriers to probabilistic risk analysis. Benefits and barriers identified during the interviews were coded using an emergent topic coding in NVivo and a matrix query. We present the results from the analysis by reporting the relative frequency of responses for benefits and for barriers.

Benefits

First, we analyzed the benefits noted in the interviews by comparing the relative frequency of benefits mentioned during the interviews. These responses were not guided, but rather open-ended, allowing interviewees flexibility in their response. After the analysis, six benefits were noted as the most frequently cited, which are shown in Table 2. These six benefits

were reported across all organizations; however, some benefits were not mentioned as frequently, for example, cost and schedule benefits were cited the least. Benefits that were mentioned less than 5% of the time were included in an *other* category.

Table 2: Interview Results – Benefits

	<i>Benefits</i>	<i>Relative Frequency</i>
1	Internal collaboration/discussion	25%
2	Ability to better manage risks	19%
3	Ability to make risks explicit	16%
4	Increased confidence in project decision making	15%
5	Ability to better manage project costs	11%
6	Ability to better manage project schedules	6%
7	Other benefits	9%

n = 186

Internal collaboration/discussion with project team and organization

Improved internal collaboration/discussion was the most cited benefit throughout the interviews. Project teams noted on several occasions that they improved their internal collaboration by conducting risk analysis on projects. One interviewee said it best, “*our number one benefit is that open dialog that gets the brain juices flowing, stops the problem before it ever occurs.*” Another interviewee stated that “*because we did it probabilistically, we could actually have the active discussion as a management team.*” Interviewees continuously noted that when probabilistic risk analysis was performed, they had more structured and effective discussions. One interview expanded the discussion by comparing the benefits of using probabilistic risk analysis with deterministic risk analysis, noting the additional value of having data that enables a better understanding of the potential risks, stating “*with deterministic you really wouldn’t be able to get that kind of insight to have that discussion.*” Further, interviewees noted discussion and collaboration benefits beyond the project team and organization, indicating increased improvement and more structured

discussions with their clients and other external stakeholders. Specifically, interviewees mentioned that they could be more explicit and transparent with their clients because they had data to support their decisions. In addition, they could actively discuss the reasoning behind decisions and requests with results from the probabilistic analysis.

Ability to better manage risks

The second most cited benefit noted throughout the interviews was the ability to better manage risk. Interviewees indicated that risk management, including risk mitigation and risk monitoring, generally improved as a result of probabilistic risk analysis. Because probabilistic risk analysis requires a more robust analysis of the risks, the resulting analysis details the risks that have the greatest impact on the project outcomes (e.g., through sensitivity analyses such as a tornado diagram). As a result, the organizations were able to focus on, and mitigate, the risks that had the largest impacts on the project. For example, one interviewee noted “*you know what to look out for and you mitigate and plan for it, or you have enough funds in reserve to accommodate it. So to me the biggest benefit is to have more assurance in executing the project.*” Additionally, risk analysis allowed organizations to narrow their risk management focus. Project teams would understand which risks are most critical to the project. As a result, they can prioritize risks to mitigate.

Ability to make risks explicit

The use of formal project risk analysis requires teams to define a comprehensive and non-overlapping set of risks. The formalization of the risk identification process results in an explicit set of risks which enhances the communication of risks within the project

organization and with the client. Teams that conducted probabilistic analysis understood what risks might occur and the impact those risks had on the project. In other words, it helped to make the risks explicit and a subject of active discussion from the beginning of the project. As a result, team members were able to think more broadly, internalizing the experience and history of others, and rationalize decisions with identified information: “[by] using probability, we are trying to look at it [the bid/estimate] in a broader view, a rationalized broader view of the experiences.” By making these risks explicit at the beginning of the project, it also enabled the teams to be proactive, versus reactive, as noted by one interviewee, “The risks are happening far less frequently because people are talking about them way ahead of time and looking for ways to solve it.”

Increased confidence in project decision making

An over-arching benefit noted frequently by interviewees was their improved confidence in decision making from the results of the probabilistic risk analysis. Project leadership and senior management of the organization saw benefits from having the results of project risk analysis results for their project decisions. One interviewee explained it as, “at least I got data to back [my decision] up and I got the analysis that says this is what the data says. You might think you might be able to pour concrete on that job faster than we ever done before, god bless ya, good luck with that, but the data says you’ll only have a 20% success if you set that number.” In contrast to deterministic analysis, interviewees indicated that probabilistic analysis provided more robust data to help inform their decisions. Many were using probabilistic analysis to avoid jobs that increased their risk exposure and select more appropriate projects to compete for, indicating, “these tools have really helped us narrow

down our work; we don't get the jobs we shouldn't get." Similarly, another interviewee stated, *"[these tools] help us to avoid the bad jobs."* As a result, they are able to make better decisions to get less, but better jobs.

Ability to better manage project costs

The ability to better manage project costs was a benefit noted by most interviewees, although not as frequently as the previous benefits. Interviewees stated that by using probabilistic risk analysis, they were able to better estimate and manage the cost throughout the project. Specifically, the outputs to probabilistic risk analysis allowed the project team to manage cost contingency and release funds as needed. One interviewee stated, *"[Based on the risks], you have a descending cumulative curve which tells you if you want to be 90 percent confident... the contract would finish within budget"*. Further, another interviewee noted the benefit of using cumulative cost distributions to manage contingency. *"The organization... uses a really nice output curve that says if I want a 50 percent chance of success on this project then I need to add 8 percent contingency. If I want an 80 percent chance of success, I need to add 11 percent contingency... it is an easy to use tool, it is not hard."* Over the lifecycle of the project, as risks expire, contingency funds can be released and reallocated to other projects within the organization.

Ability to better manage project schedules

The ability to better manage project schedules was the sixth most frequently noted benefit. Primarily, interviewees stated the ability to better estimate the project's duration and milestones: *"The biggest [benefit] is that it [probabilistic risk analysis] allows you to have*

more certainty in your ability to successfully meet a date.” Further, interviewees noted that by using risk analysis regularly for project schedule, the project team would have better discussions earlier about potential delays to upcoming milestones that could impact the project. *“It gives you the ability to have that dialogue based on either stage gates or certain milestones otherwise important to you as a leadership team.”* Project teams and organizations implementing probabilistic risk analysis are thus more aware of uncertainty in upcoming key schedule dates and can better plan for those dates. For example, one organization noted their increased ability to better estimate a long-term closure, by conducting a schedule risk analysis. The organization was therefore able to confidently estimate the duration and then communicate it clearly to the other stakeholders involved.

Validation of Benefits

In order to explore the generalizability and external validity of our results, the benefits were validated through a larger sample size with an industry-wide survey. We limited the analysis presented to individuals from the most mature risk management organizations of the sample that use probabilistic risk analysis and a comprehensive set of risk management tools. This analysis allowed us to eliminate responses from organizations that do not have in-depth knowledge of probabilistic techniques and focus on responses from organizations that use probabilistic risk analysis and realize the benefits. As a result, 29 respondents representing 25 organizations rated the benefits on a 5-point scale from very insignificant to very significant. Table 3 presents the descriptive statistics of responses.

Table 3: Validation Results – Benefits

	<i>Benefits</i>	<i>Very Significant or Significant</i>	<i>Indifferent</i>	<i>Very Insignificant or Insignificant</i>
1	Internal collaboration/discussion	76%	17%	7%
2	Ability to better manage risks	76%	24%	0%
3	Ability to make risks explicit	72%	28%	0%
4	Increased confidence in project decision making	83%	17%	0%
5	Ability to better manage project costs	76%	24%	0%
6	Ability to better manage project schedules	83%	14%	3%

n = 29

All six benefits were validated, with the overwhelming majority of survey respondents (between 72-83 percent) indicating that the benefits of using probabilistic risk analysis were either significant or very significant. Further, four of the six benefits were not rated as very insignificant and insignificant, and of the two benefits that were rated in this category, only 7% and 3% of the respondents rated these two benefits, “internal collaboration/discussion” and “ability to better manage project schedules”, respectively, as very insignificant or insignificant. Clearly, respondents acknowledged that benefits for probabilistic analysis exist and validated the benefits identified in the interviews.

Barriers

Along with the exploration of benefits, the research analyzed the barriers to probabilistic risk analysis using the same research approach. After the analysis, four barriers were noted as the most frequently cited, which are shown in Table 4. These four barriers were reported across all organizations; however, some barriers were not mentioned as frequently. Barriers that were mentioned less than 5% of the time were included in an *other* category.

Table 4: Interview Results – Barriers

	<i>Barriers</i>	<i>Relative Frequency</i>
1	Difficulty interpreting results	31%
2	Lack of organizational support	26%
3	Lack of policy and procedures	21%
4	Lack of technical expertise	6%
5	Other barriers	16%

n = 99

After initially coding the barriers into these categories, the research analyzed each of these most frequently cited barriers in-depth. This allowed us to define the barriers so that they could be addressed strategically by other organizations wishing to employ probabilistic risk analysis. The four identified barriers are explained below:

Difficulty Interpreting Results

The interpretation of results from probabilistic analyses requires knowledge of basic probability and statistics. This barrier refers to the difficulty that some project managers and team members have comprehending and using the outputs of probabilistic tools. This barrier was initially identified in the interviews as “lack of familiarity or understanding”. One interviewee, referring to probabilistic risk analysis, stated, “[it’s a] lack of a familiarity, people are not familiar with the black box and what the benefits are going to be and in some

cases, people waste a ton of effort.” Individual risk analysts (e.g., estimators, schedulers, project controls or risk management personnel) can develop the results, but the decision makers and project managers must be able to interpret, accept, and take action on the results in order to adequately use, and subsequently gain benefits from probabilistic analysis tools. Several interviewees stated the importance of illustrating the probabilistic risk analysis results in such a manner that employees and other project stakeholders can understand and interpret the implications of the results. One organization noted their transparency with all the stakeholders and discussed the training that had to occur in order to ensure everyone understood the results: *“we had representation from the different agencies so they could be part of the team and feel ownership and understand the risk management process so they could be confident in the numbers, when we start sending them the reports.”* Without confidence in interpreting the results, decision makers will not gain the full benefit of the probabilistic analysis results.

Lack of Organizational Support

The second most frequently cited barrier was the lack of support from either upper management or employees for employing probabilistic risk analysis. It is necessary to receive support from both to adopt these approaches across the organization, and, as a result, this category was mentioned frequently. In general, one upper level executive stated: *“there needs to be executive sponsorship from the top down, in order to institutionalize something in an organization.”* If there is no push from management, and no evidence of leadership support for the use of the probabilistic risk analysis, there is little chance of employee buy-in and thus use, of the approach. However, other interviewees noted the difficulty of

overcoming employee buy-in: *“Our biggest challenge is not really the technical part of the quantitative, it was selling it, it was promoting it, marketing it, how does it fit into the organization, how do you present it such that people don’t phase out. So that was one of our biggest challenges.”* Several senior managers noted the difficulty of first getting employees to accept probabilistic risk analysis, let alone implement it. Eight cases cited organizational support as extremely critical to successfully implement probabilistic analysis in an organization.

Lack of Policy or Procedures

The third barrier identified was the lack of policy or procedures for probabilistic risk analysis and, more generally, risk management. While the International Standards Organization and the Project Management Institute have standard procedures available, some organizations have not taken advantage of these standards or developed their own policies for their implementation. Other organizations were found to have policies in place, but there was minimal knowledge of the policy or a lack of policy enforcement. As a result, projects were not implementing probabilistic risk analysis consistently or with organization guidance. This was a major barrier identified within our interviews. One specific example was that some projects within the organization were implementing robust risk analysis techniques, but because corporate had not yet defined the policy, many project managers did not know the appropriate steps to take within the organization: *“What happened is we had a number of our projects within our various [business units] and some had really good grassroots efforts and had some very mature risk register procedures and processes about how they go about doing this. But it has not been adopted corporately yet to promulgate it across the business.”*

Lack of Technical Expertise

The fourth most frequently cited barrier related to two barriers, “no technical support” and “lack of familiarity or understanding”. After further reviewing these categories, the researchers classified the barrier as the lack of technical know-how to conduct probabilistic risk analysis. Overall, the interviewees noted that having an internal employee versed in risk management, probabilistic risk analysis, and the overall process was critical for implementation. Other organizations noted that outsourcing the probabilistic analysis techniques and facilitation of meetings to an external risk management consultant was also acceptable.

Validation of Barriers

In order to improve generalizability and external validity, the barriers were also validated through the larger industry-wide survey of individuals from the most mature risk management organizations. As a result, 29 respondents representing 25 organizations rated the barriers on a 5-point scale from very insignificant to very significant. Table 5 presents the descriptive statistics of responses.

Table 5: Validation Results – Barriers

<i>Barriers</i>	<i>Very Significant or Significant</i>	<i>Indifferent</i>	<i>Very Insignificant or Insignificant</i>
1 Difficulty interpreting results	76%	24%	0%
2 Lack of organizational support	83%	14%	3%
3 Lack of policy and procedures	76%	24%	0%
4 Lack of technical expertise	72%	28%	0%

n = 29

The results are very similar to the validation of the benefits, where approximately 72-83 percent of respondents noted that the barriers were either significant or very significant. Further, only one of the four barriers was rated as either very insignificant or insignificant, which was noted by only one respondent. These findings validate the barriers to probabilistic risk analysis identified in the interviews.

Discussion and Application

The primary contribution of this research was the identification and validation of the barriers and benefits to using probabilistic risk analysis on projects. During the analysis, we noted a few key overarching themes that assist in understanding why these benefits and barriers exist. In addition, a discussion is warranted regarding perceptions of organizations not currently employing probabilistic risk analysis. Finally, we offer suggestions for overcoming the identified barriers.

Because probabilistic risk analysis is conducted for project costs and schedules, we expected that the ability to better manage project costs and schedules would be the most frequently cited benefits. As seen in the validation survey results, the benefits of both cost and schedule analysis are apparent, it does provide the ability to better manage project costs and

schedules. However, our interviewees highlighted nontechnical benefits more frequently, including improved communication, improved management, and increased decision-making confidence. As a result, organizations wishing to implement probabilistic risk analysis methods should highlight the non-technical benefits arising from using risk analysis, including knowledge transfer. As our interviewees noted, the non-cost and schedule benefits will resonate with decision makers and may help to overcome the barriers of gaining top management support. For example, increased collaboration and improved confidence in decision making, although may not directly result in direct project savings, can help make the organization more effective and efficient in its project selection, sharing of lessons learned, and overall management.

Although the research highlights the importance of non-technical benefits and barriers when implementing probabilistic risk analysis, organizations must also address technical expertise and understanding. However, this appears to be an initial, versus a long-term issue. Specifically, looking at the results from the interviews and validation survey, survey respondents noted technical expertise as a significant or very significant barrier; however, it was the least frequently cited barrier in the interviews. Understandably, organizations not implementing probabilistic risk analysis have never dealt with the barriers and typically the first reservation organizations have about probabilistic risk analysis is the technical expertise necessary to use the approach. Further, organizations might have had a negative experience in the past implementing another technical technique in the organization, further hindering the organization's desire to implement additional techniques, especially if they add items on their "to do" lists without adding subsequent benefits. In contrast, organizations that had overcome this challenge focus more on the non-technical barriers. As a result, these non-technical barriers should be addressed strategically throughout the implementation of probabilistic risk analysis to encourage

successful, organization-wide adoption. In summary, the results point to a need for technical expertise in probabilistic risk analysis prior to initial implementation. For example, having a risk expert (in-house or consultant) available to illustrate the value of risks analysis and teach team members how to interpret probabilistic results was often a necessary catalyst for the organization to adopt the use of probabilistic approaches. The results also indicate, however, that organizations must subsequently address other, non-technical barriers, such as organizational change within the organization by increasing support and participation from employees across the organization.

The research sought literal replication, predicting and demonstrating that even with a diverse range of organizations (based on the defined attributes noted in the research method), benefits and barriers to probabilistic risk analysis are similar across organizations. However, our interview selection also provided evidence of theoretical replication, specifically in regards to noted differences between owners and contactors. An additional benefit identified in this research that was not in the top six results, related to external communication and transparency with project stakeholders. Although this was rated as a key benefit for project owners, it was not identified as a benefit for contractors. In fact, some contractors mentioned this transparency as a barrier rather than a benefit, consistently noting that sharing results increases their transparency of risks as well as methods. Some did not want this data to be public or easily replicated by other organizations.

Finally, the research sought to identify strategies for organizations interested in adopting probabilistic risk analysis based upon the barriers typically encountered. The four barriers identified in the research seem to be interconnected; therefore, addressing only one or two of the barriers may not be sufficient in order to implement probabilistic analysis. For example, as

interviewees noted, in order to adequately adopt policy and procedures for risk analysis within an organization, there must be true acceptance of that policy (and further enforcement) by upper management in order for successful implementation.

Organizations from the research consistently noted the need to obtain buy-in and support from employees. In our research, we found that it is typical for employees to resist culture changes within the organization – in this case, probabilistic analysis for risk management. However, successful companies from our research found that by training employees in risk management and probabilistic risk analysis and highlighting achieved benefits, employees are generally more open to adopting the new process. It is important to keep the risk management process simple and not overly time consuming. If done properly, this helped increase communication and knowledge of risks and mitigation efforts, enabling a deeper understanding of cost and schedule estimates and certainty, and enabling the organization to choose the best projects to pursue. Second, organizations that adopted formal policy and procedures, had better results in using and ultimately enforcing the use of probabilistic risk analysis and risk management on projects. This included obtaining the necessary approvals and ensuring that the appropriate parties are represented throughout the risk management and analysis process. Finally, interviewees noted the importance of explaining clearly and regularly the concept of risk management and probabilistic analysis to clients and other projects stakeholders. As a result, organizations noted that clients were more open to employing the process on their projects because they were more aware of the benefits and reasons for using probabilistic risk analysis. These three tasks – employee buy-in, implementation of policy and procedures, and stakeholder communication – were the most commonly mentioned tasks when implementing probabilistic

risk analysis; however further research on the actual adoption process to probabilistic risk is warranted.

Conclusion

The design and construction industry is filled with projects that are overwhelmed with uncertainty. Organizations are challenged to better manage these projects and the industry has tools to analyze uncertainty, yet we continuously see gaps in employing risk analysis and management. This research analyzed the benefits and barriers to applying probabilistic approaches to project risk analysis in an attempt to help organizations adopt and improve their use of this analysis. The research found clear benefits resulting from the use of probabilistic risk analysis and barriers that must be overcome to implement this analysis within organizations. This research will assist organizations in understanding and highlighting the benefits, as well as developing strategies and plans to overcome the barriers so that probabilistic risk analysis can be used. However, future research should focus on overcoming the barriers.

The research involved both qualitative and quantitative methods for analysis, which helped increase the generalizability and validity of its findings. While we addressed the “*what*” and “*why*” questions regarding the benefits and barriers of probabilistic analysis, this reported research did not address the question of “*how*” organizations successfully implement probabilistic risk analysis. The research would encourage in-depth case studies to explore policies and practices for overcoming benefits and barriers.

Although the state-of-practice and validation survey included a mix of both organizations implementing and not implementing probabilistic risk analysis, the bulk of the research, the in-depth interviews, focused on organizations that implemented probabilistic risk analysis. This

resulted in the benefits and barriers being attributed to current users and advocates of probabilistic risk analysis, and neglected the barriers experienced by those that were not using probabilistic risk analysis. Furthermore, the organizations typically implementing probabilistic risk analysis are larger organizations working on larger projects. The research therefore might only be applicable to larger firms and does not consider medium or small organizations. Future research should address the application of probabilistic risk analysis on smaller projects and when/if it is even applicable.

In addition, by focusing the research on those who use probabilistic risk analysis, we created a viewpoint that probabilistic risk analysis should be used on projects, which was not the intention. There are many instances where probabilistic risk analysis should not be used for a project, or when benefits do not outweigh the costs. In order to address this limitation, future research should focus on the concept of “when should a project or organization not use probabilistic risk analysis?” This will naturally lead the research to focus on instances and project attributes that either trigger the use or non-use of probabilistic risk analysis.

As noted in the discussion, this research also found initial discrepancy/variation of the benefits and barriers between owners and contractors. Further research investigating the differences between organization types is warranted. This research also found anecdotal evidence that probabilistic analysis improves contract risk allocation prior to contract award and improves project controls after award. However, the scope of this research did not allow a longitudinal analysis and implications, thus future research is warranted to study the long-term project impacts of using probabilistic risk analysis.

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CHAPTER 3

CONCLUSION

The design and construction industry continues to struggle with the use of risk management and probabilistic risk analysis. Although tools for identifying, assessing, and managing risk and uncertainty have existed for many years (Mak & Picken 2000; CII 2010; Kangari & Riggs 1989), the use of probabilistic approaches for risk analysis is still not common across the industry (RMRDPC 2002). Therefore, the purpose of this research was to help address this lack of use by identifying the benefits and barriers to using probabilistic risk analysis. The following chapter provides an overview of the research's theoretical contributions as well as limitations and recommended future research.

Theoretical Contributions

Based on the research question and results, key contributions were noted. The contributions focused on the initial research gap – identifying the benefits and barriers to using probabilistic risk analysis. Figure 3 re-illustrates this gap and provides the main contributions gained from this research.

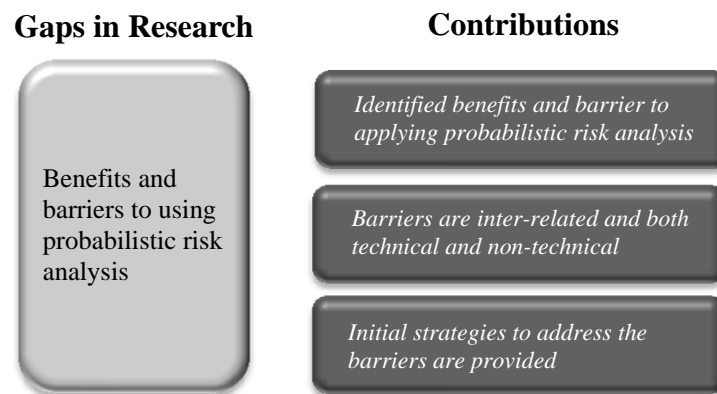


Figure 3: Theoretical Contributions

Identified benefits & barriers to applying probabilistic risk analysis

A key result to this research was identifying the benefits and barriers to probabilistic risk analysis. Six benefits and four barriers were identified during the interviews and were then verified through an industry-wide validation survey. The benefits identified included: ability to better manage project cost and schedule, the ability to better manage risks, the ability to make risks explicit, increased confidence in project decision making, and increased internal collaboration and discussion among the project team and organization. The barriers identified included: lack of organizational support, lack of policy and procedures, difficulty interpreting results, and lack of technical expertise.

Barriers are inter-related and both technical and non-technical

The identified barriers were inter-related and therefore, only addressing one barrier might not be sufficient to implement probabilistic risk analysis. For example, the lack of policy and procedures was typically a direct result from lack of organizational support. Organizations would not have the appropriate policy and procedures in place if there was no proper support and execution from senior management and project managers. Another example is the relationship between lack of organizational support and difficulty interpreting results. As noted in this research, organizations continually cited lack of support from employees, and this was a result from employees not understanding why they were employing probabilistic risk analysis and how the analysis benefited their project. Further, most of the barriers identified were not technically focused. Now this is not to say that the “lack of technical expertise” barrier should be ignored; however, this appears to be an initial, versus a long-term issue. In fact, addressing the technical barrier first was recommended by organizations.

For example, having a risk expert (in-house or consultant) available to illustrate the value of risks analysis and teach team members how to interpret probabilistic results was often a necessary catalyst for the organization to adopt the use of probabilistic approaches. From here, organizations were then able to more easily address the three non-technical barriers.

Initial strategies to address the identified barriers

The research also proposed initial strategies for addressing the barriers identified in this research. Although these strategies are not robust, it is an initial step organizations can take in moving towards using probabilistic risk analysis. The three tasks included: employee buy-in, adoption of policy and procedures, and stakeholder communication. First, organizations noted that addressing employee buy-in is essential to implementing any new technique or process within an organization. In this case, providing training and clearly illustrating the benefits was a common practice organizations took when implementing probabilistic risk analysis. Also, keeping the process simple and not time consuming was noted by organizations. Secondly, organizations using probabilistic risk analysis had defined policy and procedures in place which helped employees more easily employ probabilistic risks analysis on their projects. Policy and procedures also are critical to ensure proper use of these tools. Finally, interviewees noted the importance of clearly communicating probabilistic outputs from the risk analysis to clients and other project stakeholders. This included ensuring that all stakeholders understand the value and reasons for using probabilistic risk analysis.

Limitations & Future Research

Finally, this research had some limitations that should be addressed and considered for future research. Figure 4 outlines the main limitations and the corresponding proposed future research.

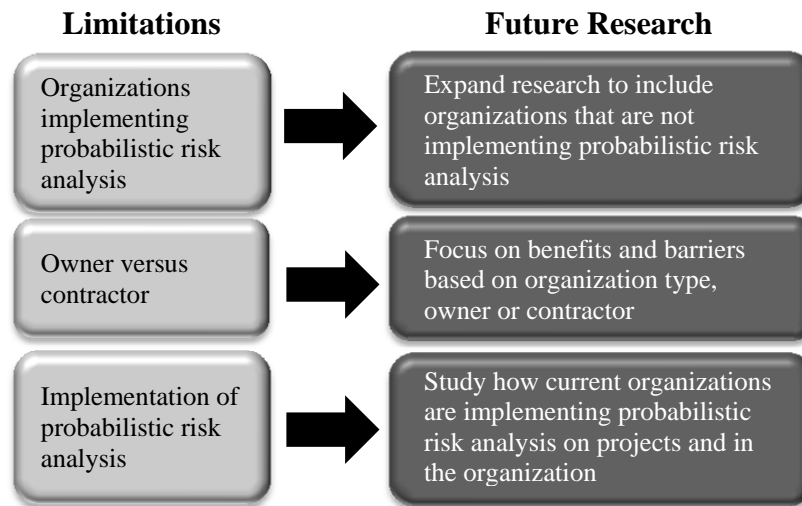


Figure 4: Limitations & Future Research

Organizations currently implementing probabilistic risk analysis

The first research limitation was that the main focus of the research only studied organizations that were implementing probabilistic risk analysis. Although this was necessary to thoroughly understand the benefits and barriers, it did not take into account viewpoints of organizations not implementing probabilistic risk analysis. Studying organizations who are not applying probabilistic risk analysis might provide more insights into barriers. The research question would focus on reasons why organizations are not using probabilistic methods. As noted in the results, there were some discrepancy between the interview findings and the validation survey, specifically in regards to the “no technical expertise” barrier. Here, organizations that were interviewed and consequently implementing probabilistic risk analysis, noted that technical expertise was a low barrier; however, on the

contrary, organization surveyed that were not implementing a robust risk management program, noted that technical expertise was a high barrier. Therefore, it is recommended that the research be expanded to include organizations that are not implementing probabilistic risk analysis in hopes of further understanding this discrepancy. However, finding organizations that are aware of probabilistic methods but have made a conscious choice not to use them might be challenging. The research method will need to be thoroughly designed in for this exploration.

Owner versus contractor

Although not a focus of this research, the research team noticed differences surfacing between owners and contractors in regards to the benefits and barriers. For example, owners raved about how probabilistic risk analysis encouraged communication among outside stakeholders and improved overall transparency. However, this was more of a barrier in the eyes of the contractor, as they would have to explain the reason for using probabilistic risk analysis, which could result in losing the bid, especially if an owner did not understand probabilistic risk analysis. In order to further the effectiveness of the findings from this research, it is recommended that additional in-depth interviews and an industry-wide survey be conducted on the differences and similarities between owners and contractors in regards to the benefits and barriers. This method would allow for further understanding of the differences that owners and contractors note in regards to probabilistic risk analysis as well as then being able to generalize the findings across the industry.

Implementation of probabilistic risk analysis

Finally, another gap in the literature that was not addressed in this research was how organizations implement probabilistic risk analysis. Future research should study the process organizations typically take when implementing and using probabilistic risk analysis on their projects as well as how do the barriers identified in this research collaborate with the implementation process. A multiple case study analysis would allow for further depth and explanation of organizations' risk management and probabilistic risk analysis processes. Ensuring proper triangulation of the data that is using multiple sources of data collection (interviews, documents, and observations) should be pursued to help validate the case study analysis.

As the design and construction industry grows, projects will continue to be overwhelmed with uncertainty. Industry leaders and organizations will need to implement new practices to include these uncertainties in their estimates and decisions in a systematic way that is both practical and widely-accepted. By becoming more familiar and cognizant of risk management, particularly probabilistic risk analysis, an organization can be more aggressive in terms of project oversight. The organization will then have more control of its projects and can be better prepared for potential uncertainties. By instituting a more robust risk strategy within the organization, a company can become more proactive, as opposed to reactive and can handle risk events more effectively.

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APPENDIX

Organizational Questions

Summary

- Context
- Risk Management and Tool Selection
- Benefits/Barriers
- Organizational Structure
- Policies and Procedures
- Funding/Training
- Lessons Learned

Context

- How does your organization define risk?
 - Enterprise , Project
- Can you provide examples of how you manage risk at the following levels?
 - *Enterprise*
 - *Project portfolio*
 - *Individual projects*
- How does your organization define contingency for cost and schedule?
- How do you evaluate if a project is risky?
 - What projects are considered: high risk? Medium risk? Low risk?

Risk Management and Tool Selection

- When do projects require formal risk analysis?
- What determines the risk analysis method used for projects?
- What outcomes do you need to help you decide which risk analysis method to use?
- What risk management and probabilistic analysis tools:
 - Has the organizations used in the past?
 - Is the organization currently using?
 - What are the tools used for?
 - How did you start using probabilistic tools?
 - When do you not use probabilistic tools?
 - Why not?
- Are the tools and processes consistently applied across projects and business units?
- How do you identify, analyze and track low probability/high impact events?

- How does this differ from high probability/low impact events?

Benefits/Barriers

- Why are you using probabilistic controls (what value do you receive/what do you hope to gain from using pc?)
- How do you know if you are receiving benefits from the use of probabilistic controls?
 - Have you done a cost/benefit analysis?
 - How do you measure your performance for risk identification and analysis?
- What frustrations do you have with:
 - Your risk analysis process?
 - With probabilistic controls?
- What impediments do you face when wanting to use/using probabilistic controls?
- How has the organization had to change to use probabilistic controls?
 - What must be in place?

Organizational Structure

- What is the organizational structure for managing risks?
 - Do you have a department /individual whose specific focus is risk management?
 - Roles
 - Responsibilities
 - Risk level focus
- How are risks communicated between the project and organization?
 - How are you informed when a risk event has occurred?
 - How are risks documented?
 - When are risk events required to be reported?
- Do you capture and use historic data for risk analysis and management?
- How is contingency estimated? Tracked and resolved?

Policies and Procedures

- Does the organization have a written policy for:
 - Risk management?
 - Contingency management?
 - Probabilistic controls?

Funding/Training

- How do you train people to use risk analysis (probabilistic) tools? Who is trained?
- How do you fund the cost, training, and maintenance of the tools?
 - Who realizes the benefit?
- What dollar amount do you allocate for risk management?
 - Probabilistic controls?
- How many people are allocated to risk analysis/probabilistic controls?

Lessons Learned

- What lessons have you learned from using probabilistic controls?
 - *What works well?*
 - *What big problems did you overcome?*
 - *What do you continue to struggle with?*
- What steps did you take after realizing these lessons?

Project Portfolio Questions

Summary

- Context
- Risk Management and Tool Selection
- Organizational Structure
- Project-Portfolio Risk Management
- Policies and Procedures
- Benefits/Barriers
- Funding/Training
- Lessons Learned

Context

- How does your organization define risk?
 - Enterprise , Project
- Can you provide examples of how you manage risk at the following levels?
 - *Enterprise*
 - *Project portfolio*
 - *Individual projects*
- How does your organization define contingency for cost and schedule?
- How do you evaluate if a project is risky?
 - What projects are considered: high risk? Medium risk? Low risk?

Risk Management and Tool Selection

- When do projects require formal risk analysis?
- What determines the risk analysis method used for projects?
- What outcomes do you need to make your decision for a risk analysis method?
- What risk analysis and probabilistic analysis tools has the organization used in the past?
- What risk analysis and probabilistic analysis tools is the organization using?
 - What are these tools used for?
 - Why did you select these tools?
 - Who selects these tools?
 - Why did you not select other tools?
 - When do you not use probabilistic tools?
- Is there a consistent tool selection process?
 - Is it based on project attributes? Outcomes/Goals needed?

- Are the tools and processes consistently applied across projects?
 - Are there “pockets” of high and low use?
 - If so, why?
- How did you start using probabilistic tools?
- How do you identify, analyze and track low probability/high impact events?
- How does this differ from high probability/low impact events?

Organizational Structure

- What is the organizational structure for managing risks?
 - Do you have a department /individual whose specific focus is risk management?
 - Roles
 - Responsibilities
 - Risk level focus
- How are risks communicated between the project and organization?
 - How are you informed when a risk event has occurred?
 - How are risks documented?
 - When are risk events required to be reported?
- Do you capture and use historic data for risk analysis and management?
- How is contingency estimated? Tracked and resolved?

Project-Portfolio Risk Management

- How do you capture and use historic data for portfolio risk analysis and management?
- How does the organization monitor risks across your portfolio of projects?
- How are “lessons learned” shared across projects?

Policies and Procedures

- Does the organization have a written policy for:
 - Risk management?
 - Contingency management?
 - Probabilistic Controls?

Benefits/Barriers

- Why are you using probabilistic controls (what value do you receive/what do you hope to gain from using pc?)
- How do you know if you are receiving benefits from the use of probabilistic controls?
 - Have you done a cost/benefit analysis?
 - How do you measure your performance for risk identification and analysis?

- How has the organization had to change to use probabilistic controls?
 - What must be in place?
- What frustrations do you have with:
 - your risk analysis process?
 - with probabilistic controls?
- What impediments do you face when wanting to use/using probabilistic controls?

Funding

- How do you train people to use risk analysis (probabilistic) tools? Who is trained?
- How do you fund the cost, training, and maintenance of the tools?
 - Who realizes the benefit?
- What dollar amount do you allocate for risk management?
 - Probabilistic controls?
- What numbers of people are allocated to risk analysis/probabilistic controls?

Lessons Learned

- What lessons have you learned from using probabilistic controls?
 - *What works well?*
 - *What big problems did you overcome?*
 - *What do you continue to struggle with?*
- How are you adjusting/have you adjusted after realizing these lessons?

Project Questions

Summary

- Overview
- Structure
- Project Controls
- Risk Management Processes
- Tools
- Benefits/Barriers
- Costs and Training
- Lessons Learned

Overview

- Please describe generally the purpose and scope of the project.
- Please describe more specifically the following project characteristics (*Note: update information from pre-visit information collection*)
 - Cost
 - Schedule
 - Scope and Complexity
 - Project Phase
 - Stakeholder Issues
 - Project Delivery Method
 - Organization of project stakeholders
 - Risk sharing agreements

Risk Management Structure

- Who is responsible for risk management for the project?
- Do you have a written policy for risk management for the project?
- What is your structure and reporting mechanisms for risk management?
 - What is used and how?
- How are you informed when a risk event has occurred?
- How do you report to the organization that a risk event has occurred on the project?
- Compared to a project that does not use probabilistic methods, what are the major differences in project structure and communication?

Project Controls

- Please describe your process for project controls in the following areas:
 - Cost
 - Schedule

- Change Management
- For Contingency:
 - Do you have a written policy for contingency management?
 - How do you estimate contingency?
 - How do you track and resolve contingency?
- How does the use of risk analysis tools change your project controls processes and effectiveness as compared to deterministic project controls?

Risk Management Processes

- For each of the following Risk Activities, please answer the 3 Risk Management Questions:

Risk Activities

- Risk identification
- Risk Assessment
- Risk Analysis (probabilistic controls)
- Risk Mitigation
- Risk monitoring and control
 - *Periodic*
 - *Immediate*

Risk Management Questions

- Who is responsible for the item?
- Does this vary across project phases?
- How often does the activity occur on each project?

For Risk Analysis specifically:

- How is risk analysis structured?
- How are the risks measured?
- How are the risks valued?
- How frequently does risk analysis occur?
- How do you re-plan?

Tools

- What tools are used for this project?
- How were the tools selected for this project?

- Were they based upon project characteristics?
 - *Influence Diagrams*
 - *Decision Trees*
 - *Simulation Analysis*
 - *Qualitative Probability*
 - *Scenario Analysis*
 - *Excel Databases*
 - *Risk Registers*
 - *Other?*
 - *Cost Parameters*
 - *Schedule Parameters*
 - *Potential for Change*
 - *Scope*
 - *Complexity*
 - *Location*
 - *Project Type*
 - *Quality*
 - *Technology*
 - *Risk Sharing*
 - *Risk Management Reporting Requirements*
 - *Project Phase*
 - *Stakeholder Issues*
 - *Safety Challenges*

- Would you have selected different tools for the project with what you know now?
 - If yes:
 - What would they be? Why?
 - Why did you not select them initially?

Benefits/Barriers

- Why are you using probabilistic controls?
- What value have you received to date on the project from your risk management activities?
- How do you measure your performance for risk identification and analysis?
- How do you know if you are receiving any benefits?
- How much time has it taken to use probabilistic controls?
- What frustrations do you have with your risk analysis process or probabilistic controls?
- What impediments do you face when wanting to use/using probabilistic controls?
- What changes do you have to make at the project level when probabilistic controls are used?

Costs and Training

- How do you fund the cost, training, and maintenance of the tools?
 - Who realizes the benefit?

- What dollar amount do you allocate for probabilistic controls? Risk?
- What numbers of people are allocated to risk analysis/probabilistic controls?

Lessons Learned

- What lessons have you learned from using probabilistic controls?
 - *What works well?*
 - *What big problems did you overcome?*
 - *What do you continue to struggle with?*
- How are you adjusting/have you adjusted after realizing these lessons?