



Construction Industry Institute®

Probabilistic Risk Management in Design and Construction Projects

Construction Industry Institute

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Probabilistic Risk Management in Design and Construction Projects

**Prepared by
Construction Industry Institute
Research Team 280, Methods for Dealing with Uncertainty:
Applying Probabilistic Controls in Design and Construction**

**Research Summary 280-1
Version 1.1
October 2012**

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Contents

<i>Chapter</i>	<i>Page</i>
Executive Summary	v
1. Introduction	1
2. Methodology	3
3. Research Findings	9
4. Interpreting Probabilistic Cost and Schedule Results	25
5. Conclusions and Recommendations	29
Appendix: Prior Research and CII	31
References	33

Executive Summary

CII created Research Team (RT) 280 to answer the following essential research question:

What would be the benefits and implications of applying a probabilistic approach to analyzing cost estimating and scheduling risks for the design and construction of capital projects?

The team's objectives included a review of the industry's current probabilistic controls practices and their associated risk allocation techniques. To make this review, the team surveyed 104 contractor and owner organizations worldwide, from which 12 were selected for in-depth case studies. For these case studies, team members conducted hundreds of hours of face-to-face interviews and collected risk-related documentation from risk managers and project teams. After analyzing the case studies and interviews, the team conducted an industry-wide validation survey of 73 organizations. The team explored when, why, and how probabilistic approaches were used, and documented the kinds of successes organizations were achieving through probabilistic risk management.

The team's final products include the following:

- identification of the benefits and limitations of probabilistic analysis
- a process roadmap for implementing probabilistic controls at three levels of risk analysis: identification, deterministic, and probabilistic
- Implementation Resource 280-2, *Applying Probabilistic Risk Management in Design and Construction Projects*, a guide to implementing probabilistic controls, with risk register templates and an example that demonstrates all three levels of risk analysis.
- Implementation Resource 280-3, *What's the Risk?*, a laminated guide to selecting the appropriate level of risk analysis and interpreting probabilistic results.

In the course of conducting the surveys and case studies, the team discovered several key advantages of using probabilistic methods over deterministic ones:

- enables better management of project costs and schedules
- enables better management of risks
- enables risk managers to make risks explicit
- increases confidence in project decision making
- improves internal collaboration and discussion with project team and organization.

Additionally, the team's initial survey results indicated that 90 percent of organizations implementing probabilistic approaches to project risk management achieve a return on investment (ROI) of at least 1:10, while a third of the respondents noted ROIs exceeding 1:100.

Key barriers included difficulty interpreting probabilistic results, as well as a lack of formal organizational policies and procedures for risk management. To help project teams overcome these barriers and implement probabilistic risk management, the team developed Implementation Resource (IR) 280-2, *Applying Probabilistic Risk Management in Design and Construction Projects*. This resource explains the general, three-level progression leading to probabilistic risk analysis the team identified in this research. The three levels of risk analysis are as follows:

- **Level 1: Risk Identification** – Identifies risks and opportunities.
- **Level 2: Deterministic Risk Analysis** – Analyzes risks through single-point estimates of potential impacts.
- **Level 3: Probabilistic Risk Analysis** – Analyzes risks through probability distribution estimates of potential impacts.

IR 280-2 contains three Excel®-based risk register templates with detailed instructions on how to identify risks and opportunities, perform deterministic analysis, and generate the three-point estimates that probabilistic cost and schedule models require.

To help organizations further realize the benefits of probabilistic risk management, the team developed IR 280-3, *What's the Risk?*, a laminated process roadmap for implementing probabilistic controls. This resource offers guidance for selecting the appropriate level of risk analysis for a project and helps users interpret probabilistic results.

Introduction

Design and construction projects can be extremely complex and are often fraught with risk and uncertainty. Project stakeholders must coordinate a multitude of human, organizational, technical, and environmental factors. Economic, societal, and political challenges can often overshadow the complexities of engineering and construction. These challenges frequently result in significant cost over-runs, schedule delays, and risk-averse contracting strategies that lead to the misallocation of resources. Implementation of probabilistic approaches provides insight into the project risks and uncertainties that affect project performance. By making risks and impacts explicit, probabilistic approaches enable team members and stakeholders to more clearly communicate and make informed decisions on project cost and schedule.

In the context of project controls, a risk is an event that can negatively affect project outcomes. Probabilistic approaches use software to model these risks and provide a range of possible outcomes. The range of project outcomes is commonly referred to as uncertainty. Good project management recognizes uncertainty and integrates risk management throughout the project life cycle. Tools for identifying, assessing, and managing risk and uncertainty for capital projects are neither new nor unique to the capital projects industry. Similarly, a risk-based mentality and vernacular have become prevalent in the current social and business climates. However, a large section of the capital projects industry employs only deterministic approaches to risk management: teams create and analyze only a single version of a schedule and budget. While these approaches have clear benefits, they give a less precise analysis of the impacts and the inherent uncertainty of known risks that can occur in planning and executing capital projects. Adding probabilistic methods to the standard suite of risk management tools allows for the cost and schedule impacts of project risks and uncertainty to be displayed graphically and used for improved project communication.

Probabilistic methods manage project risk and uncertainty in cost, scope, and schedule by taking into account known and unknown events or conditions that cannot be adequately identified or defined, either independently or comprehensively. Using probabilistic controls extends the risk management process by providing detailed numerical analysis of cost and schedule uncertainty. Probabilistic methods also account for the interdependencies that exist between project elements. They enable the integration of individual risks into an overall assessment of the combined effect of all cost and schedule risks affecting a project. The result is a probability distribution of thousands of iterations of the project's cost and/or duration, based on the risks and inherent uncertainties.

Probability distributions are a much more realistic way of capturing and communicating the likelihood of potential project outcomes. Additionally, probabilistic analysis identifies which schedule activities and risk events have the greatest impact on overall cost and schedule, allowing teams to allocate risk management resources appropriately. Probabilistic analysis also supports a comprehensive and transparent risk-based approach to establishing contingencies; this is in contrast to the way that deterministic tools frequently require the *ad hoc* application of conservative contingencies or simple standard percentages to compensate for their shortcomings.

Fifty-six percent of the organizations responding to the RT 280 survey report employing probabilistic approaches to managing project risk. Over 90 percent of the respondents indicated, at a minimum, a 1:10 return on investment (ROI), while over a third indicated an even greater ROI of 1:100. With such high returns on their investments, it is not surprising to find that many organizations are expanding their business practices to include probabilistic approaches to improving management of both project and corporate risk. In particular, respondents noted that probabilistic risk analysis helps them make risks explicit, increases confidence in project decision-making, increases knowledge transfer through internal collaboration and discussion, and allows for better management of risks, costs, and schedules.

Methodology

To identify the process, benefits, and implications of probabilistic analysis of cost and schedule risks in the design and construction of capital projects, the research team employed both quantitative and qualitative methods for data collection and analysis. Its research methodology called for a phased, mixed-method approach that allowed for an initial exploration of the “who,” “what,” and “where” of the essential research question through a literature review and a state-of-practice survey. After this initial effort, the team then explored the “how” and “why” of probabilistic methods through multiple case studies, which were followed by a second survey to validate the results. Figure 1 outlines this approach.

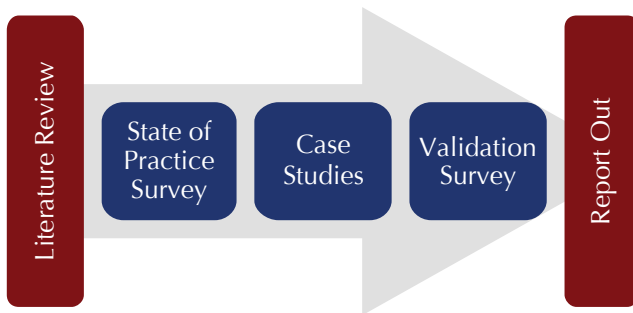


Figure 1. CII RT 280 Research Approach

Through the state-of-practice survey, the team was able to assess the use of risk management approaches and, in particular, probabilistic approaches in CII and PMI member companies. The survey also identified candidate organizations for in-depth case studies. The team selected the case study method because it allows for “depth—detail, richness, and completeness” (Flyvbjerg, 2011). In addition, case studies help answer the questions of “how” and “why” project teams are using probabilistic approaches for risk management. Thus, the case studies

provided insight into the benefits of using probabilistic approaches, the barriers that need to be overcome to use these approaches, and the process for implementing probabilistic approaches on projects. Finally, the validation survey enabled the team to generalize the findings from the twelve in-depth case studies across a larger set of organizations. This generated greater confidence in the team's findings on the use of risk management and probabilistic approaches in the design and construction industry.

Phase One: State-of-Practice Survey

The goals of the state-of-practice survey were 1) to attain a better understanding of the current use of risk management and probabilistic tools and approaches within CII and Project Management Institute (PMI) organizations and 2) to identify candidates for case studies. Distributed electronically to both CII member company contacts and members of the PMI Construction Industry Community of Practice, both in the United States and Canada, the two-part survey garnered 137 responses. The respondents represented 104 different organizations, including owners, EPC firms, contractors, and design firms. Their firms were in the infrastructure, heavy/light industrial, and commercial building sectors.

In the first section, respondents answered questions regarding organizational information—e.g., type, sector, and size, among other characteristics—to ensure appropriate representation. This information also provided selection criteria for the case studies. The second section focused on risk management and probabilistic risk management practices. The survey was primarily descriptive, since its purpose was more focused on finding out “how many” (e.g., how many organizations use probabilistic controls) as opposed to understanding “why” (Oppenheim 1992). The survey included several open-ended questions, asking participants to provide reasoning for their answers and to offer suggestions. This helped the research team develop the case study questions and identify pertinent concepts that might have been excluded from the survey questionnaire.

Phase Two: Case Studies

The goal of the case study phase was to obtain a more in-depth understanding of the use of probabilistic risk management. Aiming to address questions of “how” and “why,” the case studies primarily examined how organizations perform risk management and probabilistic methods. They investigated the reasons for using (or not using) probabilistic risk methods, and, where appropriate, how organizations began using probabilistic approaches. As shown in Table 1, the research team made sure to engage a broad spectrum of case study participants.

Case Selection

Using the results of the first survey, the team selected twelve organizations as case studies. The team chose these organizations on the basis of their use of a probabilistic approach to risk management and their representation across the following four defined attributes:

1. **Owner or Contractor** was based on the type of organization. For the purposes of this research, an organization could not be classified under both categories.
2. **Public or Private** was based on the organization’s funding source for the project(s) being studied in this research. If the organization included both government and private projects, an organization would be classified under both categories.
3. **CII Member** was based on organizational membership in the institute.
4. **Type** was based on the type of project(s) studied for this research. A participating organization could be classified under multiple types of projects. Types included: horizontal (e.g., roads, bridges, or pipelines), vertical (e.g., buildings or stadiums), and process (e.g., refinery, manufacturing, or power generation).