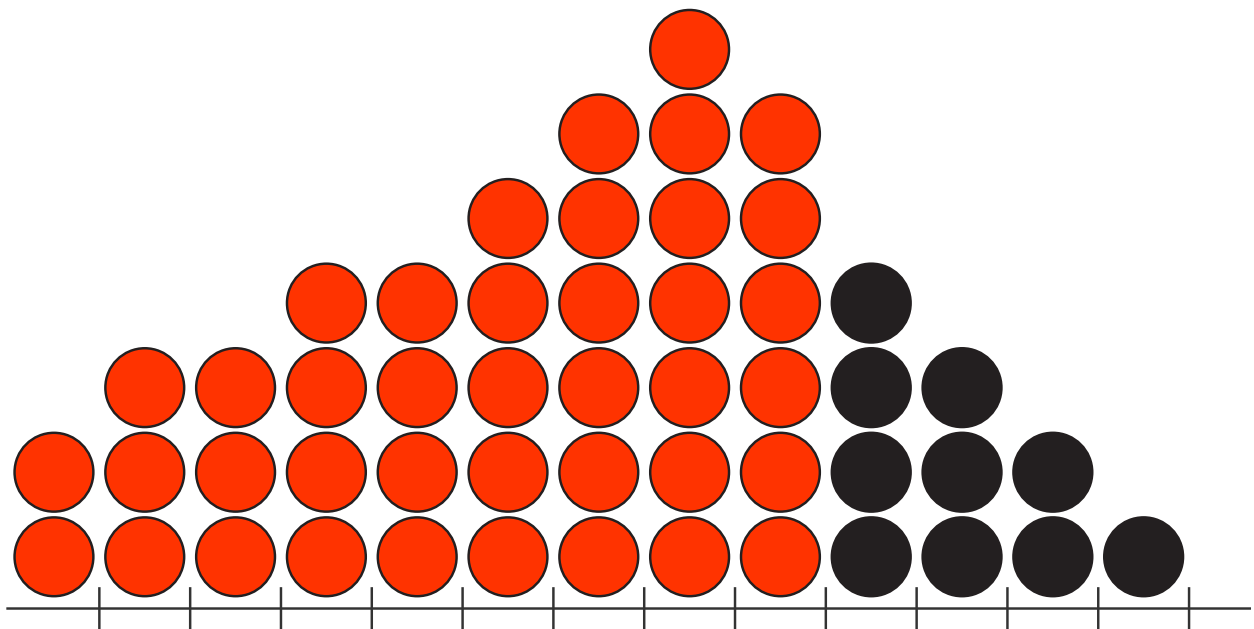


# Applying Probabilistic Risk Management in Design and Construction Projects



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|-------------------------------------------------------------|-------------------------------------------|
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| U.S. Department of Veterans Affairs                         | Yates Construction                        |
| Vale                                                        | Zachry Holdings                           |
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# **Applying Probabilistic Risk Management in Design and Construction Projects**

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

*Implementation Resource 280-2  
Version 1.2  
March 2013*

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The University of Texas at Austin

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# 1. Introduction

CII Research Team (RT) 280 developed this comprehensive guide to probabilistic risk analysis, first to help organizations determine whether the probabilistic approach is appropriate for their projects, and, if appropriate, to help them implement it. The guide takes the user through the typical steps of adopting probabilistic risk analysis, from identifying risks to interpreting a probability distribution. In addition to this process description, the guide also provides an overview of the interactive risk register tool developed by the research team. Along with this overview and instructions, it offers an example of a construction project that uses the tool.

## Benefits of Probabilistic Risk Management

In the course of conducting the case studies that were a part of the RT 280 research process, the team interviewed project managers who used probabilistic methods for risk management. These interviewees consistently reported that, among the biggest advantages of using this type of risk analysis, is its ability to give them more certainty in their capacity to successfully execute a project by a set completion date. They reported that probabilistic controls enable them to anticipate, plan for, and mitigate extra costs and delays. After analyzing the data from the case studies, the team determined that the key advantages of using probabilistic over deterministic risk analysis include the following:

- **Comprehensive risk assessment** – Results incorporate the cumulative effect of known risks and the quantification of project uncertainties.
- **Clear visual representation** – Graphic representation of results allows for robust means of communicating risk, including probability density graphs, cumulative distributions, and tornado diagrams.
- **Communication** – The method allows for clear communication of project cost or schedule uncertainty to stakeholders.
- **Confidence in project outcomes** – Results provide additional data to support decision making and illuminate the possible outcomes of decisions.
- **Ability to manage cost and schedule** – The method assesses the impact of risk events on project cost or schedule performance and the likelihood of achieving project outcomes.

Additional information and details on the case study analysis can be found in Research Summary 280-1, *Probabilistic Risk Management in Design and Construction Projects*, and Research Report 280-11, *Methods for Dealing with Uncertainty: Applying Probabilistic Controls in Design and Construction*.

## Risk Management Levels

In order to address the benefits and implications of using a probabilistic approach, the research team had to determine the process and framework for implementing probabilistic approaches. Based on the case study analysis, the team developed a three-level approach. Implementation Resource (IR) 280-3, *What's the Risk?*, presents the three levels of risk management, along with information on interpreting probabilistic results. The levels, as identified by the research team, are presented in Figure 1, with brief definitions.

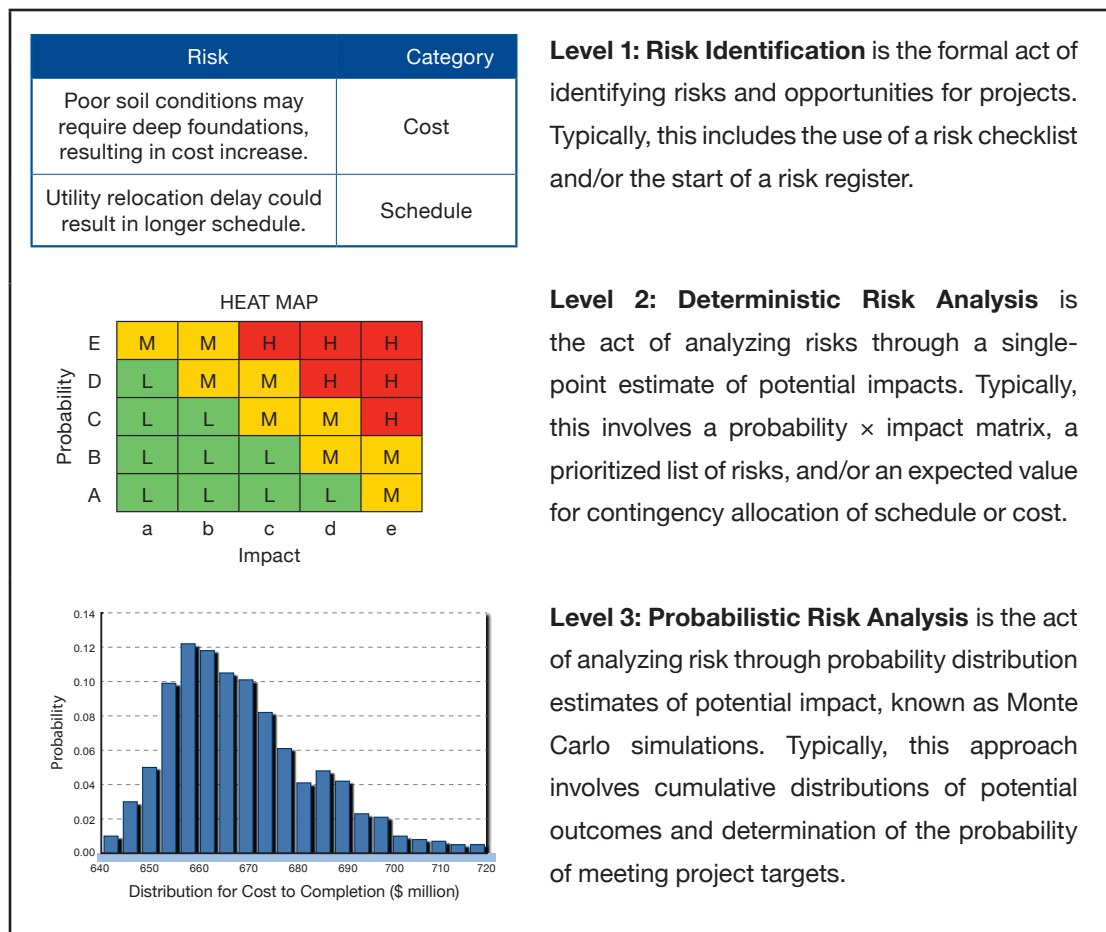


**Figure 1.** The three levels of risk management

Because these three levels provided a clear framework for evaluating and categorizing the case study data, formulating them helped the research team assess the similarities and differences among the organizations studied; using the framework, the team was better able to understand how each organization implements project risk management and probabilistic approaches. The three-tiered framework also made it easier to define, compare, and understand the benefits and barriers the organizations experienced at each level.



## 2. Example Project Using Risk Management Levels

To facilitate the implementation of the research, the team developed the three separate risk registers included with this guide. These registers correlate to the three levels of risk analysis: Level 1 – Risk Identification; Level 2 – Deterministic Risk Analysis; and Level 3 – Probabilistic Risk Analysis. This section explains how to use the risk register for each level and how to interpret the sample outputs of an actual bridge construction project.

### Project Context

To improve safety, a city is planning to change an at-grade intersection to a grade-separated interchange. The construction will occur at highways US 555 and SH 111, in a rapidly-developing suburban area. The highways have inadequate capacity and are expensive to maintain. They are also the only viable east-west (US 555) and north-south (SH 111) routes for commercial traffic for several miles in either direction. The existing and proposed site plans are provided in Figures 2 and 3.

The project will upgrade the existing unlimited-access, two-lane US 555 into a limited-access, four-lane highway. This improvement will include reconstruction of the existing roadway section. The city anticipates that, where possible, US 555 will be widened to the north of the existing facility, since right-of-way is more readily available to the north. If, as assumed, the roadway embankment is supported by retaining walls, widening the road to the north will affect a 10- to 15-foot-wide strip of existing Class III wetlands along the eastern half of the upgrade. This widening will also require construction near a historic building to the south and the crossing of Wandering Creek, which is home to protected salmon and other animal species. The project will also involve upgrading the existing unlimited-access, two-lane SH 111 into a limited-access, four-lane highway. This change will include the reconstruction of the existing roadway section. Finally, the project will convert the at-grade intersection of US 555 and SH 111 into a grade-separated interchange.

## 2. Example Project Using Risk Management Levels

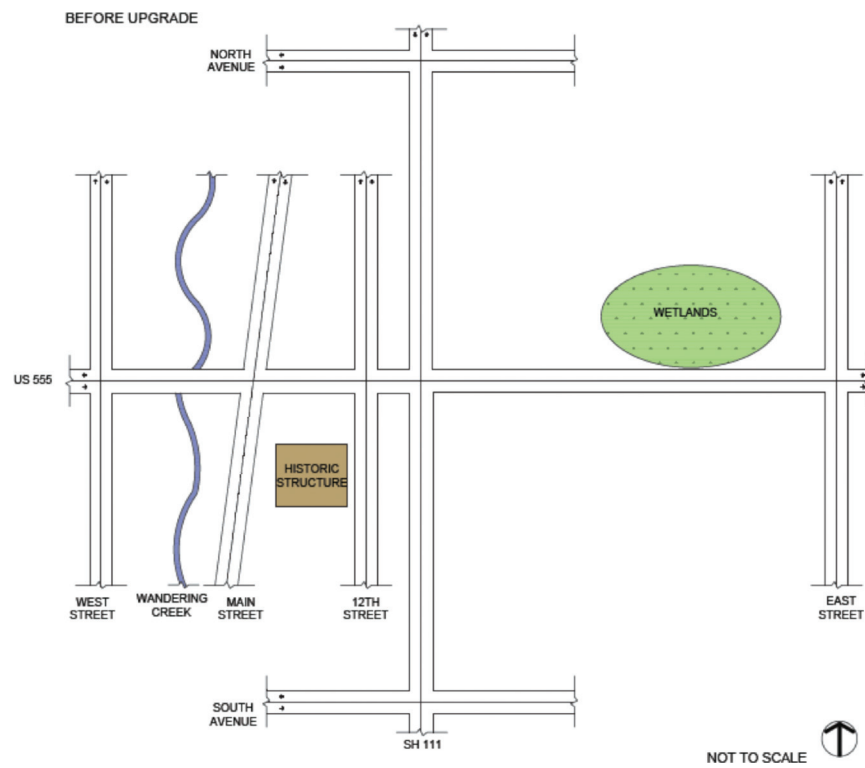


**Figure 2.** Existing site plan

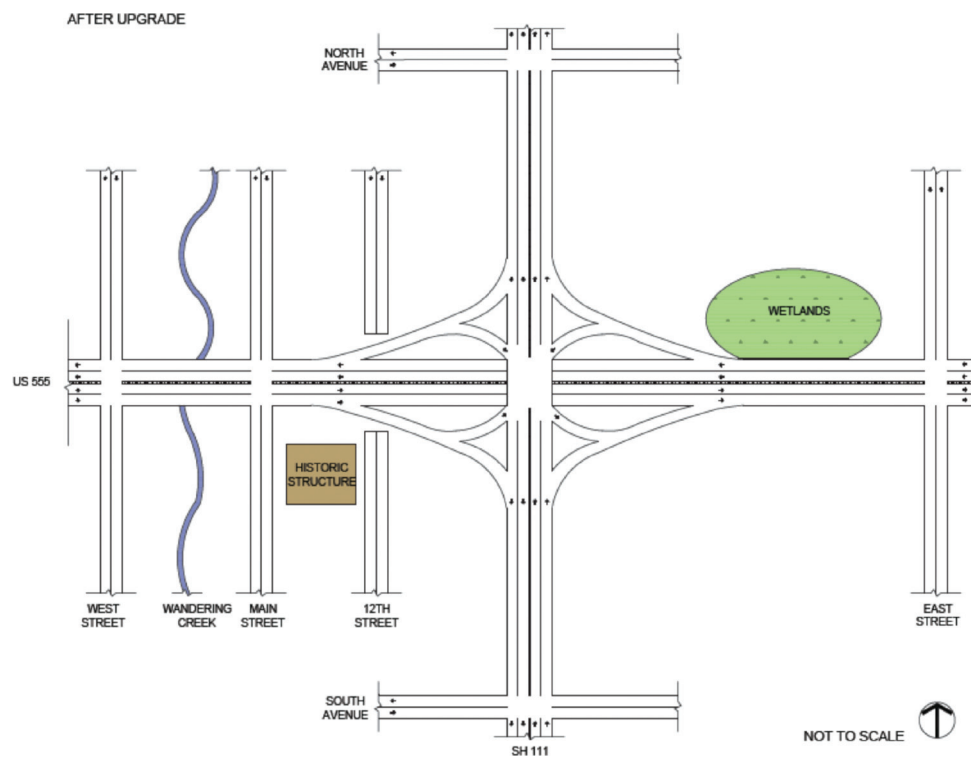


**Figure 3.** Proposed site plan

## Application of Level 1: Risk Identification

At an early stage in the design, the city conducted a facilitated risk identification workshop to identify, categorize, and document the risks for the project. The project team gathered preliminary data for the workshop, including the project scope description, cost estimate, and construction schedule. The team members were certain to include all the assumptions about scope, schedule, and cost estimate, as well as any allowances and contingencies that were made as they were developed. While the city had hired outside consultants to lead their risk workshops in the past, this workshop was facilitated by an internal team member who was knowledgeable in risk management and had risk elicitation training. The facilitator brought a series of risk checklists maintained by the city to ensure that the team did not miss any commonly encountered risks. However, these were only used after the team had completed its brainstorming about project risks.

Key project team members attended the workshop, including the project manager, design manager, construction manager, and safety officer. People from outside the project team also attended, including internal discipline leads, a few managers with experience from other projects, and a few external consultants, including an environmental consultant. The workshop facilitator began by asking the team members to express their key issues and concerns with the project (i.e., what was keeping them up at night). After a few hours of structured brainstorming and discussion, which included an examination of the design/estimating and scheduling assumptions, the team ended up with a categorized list of approximately 50 risks. Figure 4 presents some of the risks identified in this session. In addition to identifying and describing the risk, the project team also determined the project phase at which the risk could occur and the category of its impact (i.e., cost or schedule).

At this point in the project life cycle (design), if the city only wanted to identify the risks and did not want or need to conduct a more robust analysis, the city would most likely use its historic contingency average of 10 percent and manage the risks identified in this Level 1 risk identification workshop. Accordingly, the team would have budgeted approximately \$24 million.

| LEVEL 1 – RISK IDENTIFICATION |           |                   |                                        |                                                                                                                                                                       |                      |                    |
|-------------------------------|-----------|-------------------|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|--------------------|
| Item                          | Status    | Date Identified   | Brief Risk Description                 | Detailed Risk Description                                                                                                                                             | CII Project Phases   | Category of Impact |
| Manual                        | Drop Down | Manual (MM/DD/YY) | Manual                                 | Manual                                                                                                                                                                | Drop Down            | Drop Down          |
| 1                             | Active    | 09/14/12          | Historic site approval                 | On-site structures may be eligible for historic register causing project delay.                                                                                       | Front End Planning   | Schedule           |
| 2                             | Active    | 09/15/12          | Change in pavement section and/or type | Traffic studies may result in a change in pavement section and/or type resulting in a project cost increase.                                                          | Detailed Engineering | Cost               |
| 3                             | Active    | 09/15/12          | Replace culvert over Wandering Creek   | If required by the hydraulic study, the culvert at Wandering Creek may need to be replaced resulting in a project cost increase.                                      | Front End Planning   | Cost               |
| 4                             | Active    | 09/15/12          | Additional wetland mitigation          | Widening to the north will impact a 10- to 15-foot-wide strip of existing Class III wetlands along the east half of the upgrade, causing an increase in project cost. | Detailed Engineering | Cost               |
| 5                             | Active    | 09/15/12          | Delay in request for proposal          | The city may not meet its RFP development schedule, resulting in a project delay.                                                                                     | Procurement          | Schedule           |

Figure 4. Identified risks

## Application of Level 2: Deterministic Risk Analysis

The city felt that the risk identification workshop did not provide enough information for this project, due to the uncertainty and intuitively high costs associated with the identified risks. In addition, city staff felt that the identified risks should be prioritized. Thus, the city decided to progress to Level 2, deterministic risk analysis. Using the same facilitator and team from the risk identification workshop, the city first defined the meaning of “impact” and “probability” for this specific project. The facilitator and the workshop team completed the Level 2 risk register input sheet. (See Figure 5.)

| Category of Impact |                                                    |       |     |             |             |
|--------------------|----------------------------------------------------|-------|-----|-------------|-------------|
| Cost               |                                                    |       |     |             |             |
| Description        |                                                    | Value |     | Mean Value  |             |
|                    |                                                    | L     | H   | (Dollars)   |             |
| VL                 | Insignificant Cost Increase                        | 0%    | 0%  | \$0         |             |
| L                  | Minimal Cost Increase                              | 0%    | 5%  | \$450,000   |             |
| M                  | Significant Cost Increase                          | 5%    | 10% | \$1,350,000 |             |
| H                  | Very Significant Cost Increase                     | 10%   | 20% | \$2,700,000 |             |
| VH                 | Critical Cost Increase                             | 20%   | 40% | \$5,400,000 |             |
| Schedule           |                                                    |       |     |             |             |
| Description        |                                                    | Value |     | Mean Value  |             |
|                    |                                                    | L     | H   | (Days)      | (Dollars)   |
| VL                 | Impact recoverable without affecting critical path | 0%    | 0%  | 0.0         | \$0         |
| L                  | Impact recoverable affecting critical path         | 0%    | 5%  | 27.4        | \$547,500   |
| M                  | Critical path affected                             | 5%    | 10% | 82.1        | \$1,642,500 |
| H                  | Restructuring of project required                  | 10%   | 20% | 164.3       | \$3,285,000 |
| VH                 | Major restructuring of project required            | 20%   | 40% | 328.5       | \$6,570,000 |

| Risk Probability Ranking |                                   |       |      |
|--------------------------|-----------------------------------|-------|------|
| Description              |                                   | Value |      |
|                          |                                   | L     | H    |
| vl                       | Very low likelihood of occurring  | 0%    | 10%  |
| l                        | Low likelihood of occurring       | 10%   | 30%  |
| m                        | Medium likelihood of occurring    | 30%   | 50%  |
| h                        | High likelihood of occurring      | 50%   | 70%  |
| vh                       | Very high likelihood of occurring | 70%   | 100% |

**Figure 5.** Deterministic impact and probability assessment