Application of Quantitative Risk Management Practices to Project Development: A Survey of State Practice and Related Research

Requested by
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Executive Summary

Background

Currently, Caltrans' Capital Outlay Support (COS) program employs quantitative risk management practices to contain costs associated with the construction of transportation projects. COS management is interested in learning about a different application of quantitative risk management practices, one that assesses risk earlier in the life cycle of a transportation project—before the project reaches the construction phase. These practices would assess and quantify the risks encountered during project development, when project teams produce plans and specifications, develop cost estimates, complete environmental evaluations and advertise to the construction community.

Caltrans would like to learn from the experiences of other transportation agencies applying this type of risk management. To assist Caltrans in this information-gathering effort, CTC & Associates examined domestic and international published and in-process research that addresses the application of quantitative risk management practices to transportation project development. To supplement the literature review, CTC contacted members of the AASHTO Standing Committee on Planning to inquire about the member agencies' quantitative risk management practices during project development.

Summary of Findings

We sought information about the use of quantitative risk management practices applied during project development using a literature search and contacts made to representatives of state departments of transportation (DOTs) who indicated that these practices were employed by their agencies. We begin below with results of the state DOT queries.

Consultation with State DOTs

We sent an email query to members of the AASHTO Standing Committee on Planning seeking to identify state agencies applying quantitative risk management during the project development process. Responses to that query prompted us to follow up with representatives from six state DOTs—Minnesota, Nevada, New York, Utah, Virginia and Washington—to gather more information. A seventh state—Vermont—is developing quantitative risk management practices for use during project development but had nothing to share at this time.

The following describes some common themes identified in our conversations with these six agencies and a review of documents describing the agencies' practices.

Background

Washington State DOT was an early adopter of quantitative risk management during project development. WSDOT began development of a formal risk assessment process—Cost Estimate Validation Process (CEVP)—in 2002 and initiated its use on a set of projects in 2003. Nevada DOT began conducting its version of quantitative risk assessment in the summer of 2008. Since 2009, New York State DOT has adopted quantitative risk management to a lesser degree, applying the practices on a handful of projects. Utah DOT first investigated the use of WSDOT's CEVP model on a problematic project more than 10 years ago. Four years ago, UDOT revisited its risk management program, employing a full-time staff member to oversee the agency's risk management activities. Minnesota DOT began applying quantitative risk management practices to a large program of projects in 2013. In Virginia, traditional and design-

build projects are subject to qualitative assessment, while quantitative risk practices, in varying degrees, are applied to public-private partnership projects.

The Process

The quantitative risk management processes employed by five of the six states we spoke to—Minnesota, Nevada, New York, Utah and Washington—are similar. The process begins with a workshop to bring together a range of interested parties—the project manager and team, internal and external subject matter experts, cost estimate and construction experts, and other specialists as needed—to identify and quantify risks early in the project development process. These workshops can be led by consultants or by trained in-house staff. A quantitative tool is used to assess the risk data gathered during the workshop. All states conduct some form of follow-up after completion of the initial workshop and generation of risk-related documents to track risks throughout the phases of project development.

The Quantitative Tool

States have a range of qualitative and quantitative tools to address risk management during project development and most often use project cost as a general guideline in determining which tool to use. Quantitative risk management processes that employ a consultant's probabilistic modeling tool are typically applied to large projects of $100 million or more or to projects of lower cost but significant complexity. Instead of using project cost to determine when to apply quantitative practices, MnDOT applies a set of complexity definitions.

Typically, these tools apply a Monte Carlo simulation technique to determine the impact of risks identified by workshop participants by running simulations that identify a range of possible outcomes for multiple scenarios. Some states maintain their own Excel-based quantitative tools that are developed in-house or by a consultant for use with lower-cost projects. These tools may also apply Monte Carlo simulation techniques. Tool output includes risk registers that quantify and rank risks, tornado diagrams, expected values and decision trees.

Risk Management Program Impacts

While some states note the challenges of quantifying the benefits of risk management, NDOT cites significant cost savings resulting from quantitative assessment of a major program of projects in Las Vegas. MnDOT has found that cost estimates developed with the aid of quantitative risk assessment are let close to or under the budget initially developed. For UDOT, the benefits of risk management also lie in the communication that occurs during the risk workshop, bringing people together to bridge gaps in the agency. WSDOT offers anecdotal evidence that quantitative risk management results in better cost estimates and the establishment of risk reserves, and better equips project managers to address issues that arise in the field.

Challenges

Below are some of the challenges identified by interviewees:

- Finding time to conduct the workshop and integrate findings into a procurement document can be challenging.
- Striking the right balance of quantifying and managing risk with the most effective use of limited resources can be difficult.
- Holding project managers accountable for costs over the life cycle of a project's development can represent a culture change.

- Earning staff confidence and demonstrating competence in the process can take time.
- Risk registers can become too cumbersome when they include 50 to 100 items. Not everything has to be assessed using a quantitative model.
- The ranking of risks generated by some software programs can be misleading, and the project team may fail to pay adequate attention to high-impact, low-probability risks.

Recommendations for Success

Interviewees offered these and other recommendations to agencies implementing a quantitative risk management program during project development:

- Ensure executive and management support.
- Be patient and start small.
- Employ an effective facilitator to lead the risk workshops.
- Avoid shortchanging the philosophical assessment of risk management in favor of a sole focus on tools.

Federal Highway Administration Analysis Required for "Major Projects"

Our discussion with NDOT brought to light a legislatively mandated requirement for Federal Highway Administration (FHWA) to examine financial plans submitted by state DOTs undertaking a "Major Project" as defined by the rule (projects with a total cost exceeding $500 million or with high visibility). FHWA applies a risk-based probabilistic assessment, similar to the assessments conducted by NDOT and other states interviewed for this Preliminary Investigation, to ensure that the state-provided cost estimates are "reasonable and supportable."

Other State DOT Quantitative Risk Management Practices

To supplement the information obtained through interviews, we gathered information from agency web sites and other sources about the quantitative risk management practices used by other state DOTs during project development. We highlight the practices of three state DOTs:

- *Florida DOT*. Levels of risk analysis include a consultant-led independent risk analysis workshop for complex projects or projects with total costs greater than $500 million.
- *Montana DOT*. Project cost determines the level of risk analysis during estimating and design project management. Rarely does the agency expect to apply the Cost Risk Assessment workshop specified for complex or major projects.
- *Ohio DOT*. The agency's new cost estimate review process is similar to FHWA's examination of cost estimates associated with FHWA-classified Major Projects.

Domestic Research and Resources

In this section we provide a sampling of publications from FHWA, NCHRP and Strategic Highway Research Program 2 (SHRP 2) that offer guidance on quantitative risk analyses. We also provide additional information about the quantitative analysis FHWA conducts on projects classified as Major Projects, and details of an NCHRP project in process, scheduled to conclude in October 2015, that is expected to identify tools and techniques state DOTs can use to manage risk across the agency.

International Research and Resources

In this section we highlight conference papers that describe a new quantitative model used in connection with Australian road projects, and a standard for cost estimation for projects that require funding from the Australian government. Also included in this section are an international scan report that identifies structures for successful risk management and a practice standard for project risk management issued by an international project management organization. The final citation in this section revisits the CEVP model developed for WSDOT in a discussion of how the model has been applied to large transportation projects in Canada.

Gaps in Findings

The summaries of consultations with six state DOTs are not intended to represent an exhaustive review of the activities among state DOTs in the area of quantitative risk management. It also appears that agency practices are evolving, with these summaries representing a snapshot in time.

We received a relatively low level of response to our initial inquiry, and other state DOTs not identified in this report may support robust risk management programs that conduct a quantitative assessment of risk during the phases of project development.

Next Steps

Moving forward, Caltrans could consider:

- Contacting any of the states identified in this Preliminary Investigation as using quantitative risk management practices during project development to gather more information about specific areas of interest to Caltrans. These contacts might address:
    - The staffing needs and training requirements to support quantitative risk assessment practices during project development (Florida, Minnesota, Nevada, New York, Utah and Washington).
    - The role of workshops in gathering the information needed for risk analysis (Florida, Minnesota, Nevada, Ohio, Utah and Washington).
    - The development of agency tools (NDOT's Cost Estimating Wizard, UDOT's Excel-based risk model for Monte Carlo analysis and WSDOT's risk-based estimate self-modeling tool).
    - The role played by consultants in the risk management process (Florida, Minnesota, Nevada, Ohio, Utah and Washington).
- Contacting Vermont Agency of Transportation to learn more about its ongoing activities to initiate a quantitative risk management program that examines risks during the phases of project development.
- Consulting with NYSDOT later this year to inquire about the impact of the relatively new Office of Project Management in formalizing risk management practices across the agency.
- Contacting MnDOT in early 2016 to learn more about the guidance documents now in development that will provide further direction on what is needed to conduct a quantitative risk assessment and when it is most appropriate to conduct this type of analysis.

Detailed Findings

Consultation with State DOTs

We distributed an email to members of the AASHTO Standing Committee on Planning to seek information from agencies applying quantitative risk management practices to the project development process. We received responses from 11 state DOTs that can be categorized as follows:

- Not currently applying quantitative risk management practices during project development—Arkansas, Connecticut, Missouri and North Dakota.
- Currently developing quantitative risk management practices for use during project development—Vermont.
- Using a risk evaluation matrix—Virginia.
- Currently applying quantitative risk management practices during project development—Minnesota, Nevada, New York, Utah and Washington.

Below we summarize our conversations with representatives from six state DOTs—Minnesota, Nevada, New York, Utah, Virginia and Washington—about the agencies' use of quantitative risk management practices during project development.

The summaries below are organized in the following topic areas:

- Background.
- The Process.
- The Quantitative Tool.
- Implementing the Process.
- Risk Management Program Impacts.
- Challenges.
- Recommendations for Success.
- What's Next.
- Related Resources.

Not all summaries include all topic areas.

Minnesota

Contact: Christopher Roy, State Design Engineer, Minnesota Department of Transportation, 651-366-3182, chris.roy@state.mn.us.

Background

Christopher Roy notes that MnDOT has long been conducting some form of risk management, but the agency's practices have evolved over time. During the period 2007 to 2009, a cost estimating and cost management initiative within the agency led MnDOT to consider a more

comprehensive approach to risk management; see Related Resources for a technical manual that describes the agency's risk management processes.

While MnDOT had demonstrated its proficiency in estimating costs, it was determined that more work could be done on controlling the scope of a project and measuring risk, which pointed to a new focus on risk management. As Roy indicates, the agency was expending significant efforts on developing a risk register—with a project team spending a day or more developing the register—while less time was typically devoted to monetizing risk, examining the basis for the probabilities and costs associated with each item in the register.

The Corridors of Commerce program, created by the Minnesota Legislature in 2013 to fund the construction, reconstruction and improvement of trunk highways, presented an opportunity for MnDOT to apply its quantitative risk management practices to a set of 11 projects.

The Process

All MnDOT projects, regardless of project size and complexity, require some form of qualitative or quantitative risk assessment. Unlike other agencies, MnDOT does not use project cost to determine which projects will be subject to a quantitative risk assessment. Instead, the agency applies a set of complexity definitions developed by Pennsylvania DOT that appear in *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction* (see page 29 of this Preliminary Investigation for a citation for this publication). Projects identified as "major projects" under this criteria are subject to a quantitative risk analysis, referred to in MnDOT documents as a Type III risk analysis. Complex smaller projects may also be subject to more than simply a qualitative assessment using a risk register.

A Type III risk analysis for a major project requires a consultant-led risk analysis workshop to identify project risks. The analysis begins with the project's schedule and cost estimate. Workshop participants provide a "three-point estimate" that reflects the optimistic (low), most likely and pessimistic (high) values for the activity or cost element. A quantitative Monte Carlo simulation conducts a simultaneous evaluation of the impact of all risks identified and quantified by the workshop participants. For other projects not deemed to require a consultant-led workshop, MnDOT uses an internal Monte Carlo tool to quantify project risks.

The Quantitative Tool

MnDOT's consultant-led risk workshops have employed the @RISK tool by Palisade, which is used in conjunction with Excel to apply Monte Carlo simulations by using the project team's risk-related qualitative assessments to calculate and track multiple scenarios, and identify the probabilities and risks associated with alternatives. Risk workshop products include a risk register and risk management plan. Risk management plans that result from risk workshops are updated frequently as circumstances require.

For medium-size and larger projects not subject to a risk workshop, MnDOT uses Deltek Acumen Risk. This Monte Carlo risk analysis tool produces a risk register that allows the agency to examine alternatives to identify the most effective risk response plans for both cost and schedule. MnDOT first used this tool to consider schedule risks during construction. The tool can be used at the project level or on specific project segments.

Risk Management Program Impacts

At various times, MnDOT has received an influx of unexpected funding from sources such as the state-funded Corridors of Commerce program and the American Recovery and Reinvestment Act of 2009. Roy notes that the large programs of projects developed to apply these funds can present challenges to planners. In some cases, not every project identified in the initial stages of programming can be built as proposed when cost estimates may be subject to significant fluctuation. With the application of quantitative risk management practices to its first five projects for the Corridors of Commerce program, Roy notes that only one of the five projects was let over its estimated cost, while the other four projects were let 20 percent under the initial cost estimate. Roy notes that, ideally, projects will be let on target with the initial estimate, and not above or below.

Challenges

Moving to a formalized quantitative risk assessment program can represent a culture shift for project managers who will be held accountable for the budget on a project that could be four years away from letting. However, Roy notes that the quantitative tools allow project managers to make informed decisions on how to hit a project cost target as the project life cycle unfolds.

What's Next

MnDOT is developing white papers that will provide additional guidance on what is needed in connection with quantitative risk management and when it is most appropriate to employ the quantitative practices for MnDOT projects. Roy expects these guidance documents to be available by early 2016.

Related Resources

Cost Estimation and Cost Management, Technical Reference Manual, Minnesota Department of Transportation, 2008.
http://dotapp7.dot.state.mn.us/edms/download?docId=670233
The manual highlights the following issues to consider:

- *Project complexity*. Project complexity is the key driver for determining the type of risk analysis. Project size is not necessarily a determinant of project complexity. Small projects can be complex and require a more rigorous analysis.
- *Use of consultants*. Employ external consultants for Type III risk analyses. Retain the consultant who conducts the initial risk analysis for updates, whether periodic or as required by project circumstances.
- *Resulting risk management plan*. Develop risk management plans and update them frequently. The level of detail in the risk analysis plan corresponds to the level of risk management.

The following sections of the report provide more in-depth discussion of issues related to quantitative risk practices:

- Risk register (see page 428 of the report; page 434 of PDF).
- Estimate ranges—Monte Carlo analysis (see page 437 of the report; page 443 of the PDF).
- Risk workshops (see page 440 of the report; page 446 of the PDF).

The Project Risk Management Process, Minnesota Department of Transportation, undated.
http://www.dot.state.mn.us/pm/documents/guidance/The%20Project%20Risk%20Management%20Process%20SHORT%20(2).docx
This draft document describes MnDOT's risk management process and provides links to other risk management topics, including quantitative risk management.

Quantitative Risk Analysis—Level 3, Minnesota Department of Transportation, undated.
http://www.dot.state.mn.us/pm/documents/guidance/quantitative-risk-analysis.docx
This document describes the quantitative tool used to conduct the risk analysis and how a risk register is used to enter data that will be used in the quantitative analysis.

@RISK6, Palisade Corporation, 2015.
http://www.palisade.com/risk/
From the web site:

> @RISK (pronounced "at risk") performs risk analysis using Monte Carlo simulation to show you many possible outcomes in your spreadsheet model—and tells you how likely they are to occur. It mathematically and objectively computes and tracks many different possible future scenarios, then tells you the probabilities and risks associated with each different one. This means you can judge which risks to take and which ones to avoid, allowing for the best decision making under uncertainty.
>
> @RISK also helps you plan the best risk management strategies through the integration of RISKOptimizer, which combines Monte Carlo simulation with the latest solving technology to optimize any spreadsheet with uncertain values. Using genetic algorithms or OptQuest, along with @RISK functions, RISKOptimizer can determine the best allocation of resources, the optimal asset allocation, the most efficient schedule, and much more.

Deltek Acumen Risk, Deltek, Inc., 2015.
http://www.deltek.com/products/ppm/risk/acumen-risk
From the web site:

> Acumen Risk is a Monte Carlo risk analysis tool combining true cost and schedule risk analysis against a native project plan together with identified risk events from a project risk register.

Nevada

Contact: Amir M. Soltani, Project Management Chief, Nevada Department of Transportation, 775-888-7321, asoltani@dot.state.nv.us.

Background

In the summer of 2008, NDOT began conducting Cost Risk Assessments (CRAs) to quantify the risks associated with major capacity projects (over $100 million) and innovative delivery projects such as design-build.

Today, most of the projects NDOT subjects to a comprehensive quantitative risk analysis are large projects. Amir Soltani estimates that the agency conducts about eight CRAs a year. The agency conducts more limited risk assessments on specific elements of a project that have been deemed to present the potential for significant risk. For example, the agency has completed a CRA on the contractual aspects of certain design-build projects.

NDOT limits its application of quantitative risk management to major capacity projects. The NDOT Cost Estimating Wizard, a cost-estimating tool used for lower-cost projects since 2007, is addressed later in this summary.

The Process

A facilitated CRA workshop is required on projects with total project costs over $100 million and highly suggested for projects between $10 million and $100 million. The workshop facilitator is trained in risk assessment and analysis, and in the application of a probabilistic tool that analyzes risks with potential impact on the project's scope, budget and schedule. Participants in an NDOT CRA include the consultant representatives leading the session, members of the project and cost-risk teams, and internal and external subject matter experts.

The Quantitative Tool

The risk management tool used in NDOT's CRAs was developed by HDR, Inc., an international engineering firm. (Soltani notes that the HDR tool is similar to the tool used in CEVP to support WSDOT's risk management program; see page 20 of this Preliminary Investigation for information about the WSDOT process.) The tool generates:

- *Probabilistic modeling.* The user enters the probability that each risk will occur, along with estimates of cost and schedule impact (low, high and most likely). The model evaluates up to 20 risks.
- *Risk registers.* These simple spreadsheets allow the agency to track the risks identified in the CRA.

The CRA reports included in Related Resources provide examples of the quantitative tool's output.

NDOT has an internal version of this tool, developed in 2008, that does not include updates or enhancements reflected in the HDR tool currently used in CRA workshops. NDOT often uses its internal tool to more closely manage specific elements of a project, such as right of way.

Design-build projects use the same risk management tool as traditional projects. An independent cost estimate from a contractor not competing to bid on the project provides additional information about the design-build project to help the agency better understand construction and other project risks.

NDOT conducts follow-up on all projects, updating costs every year or at least every two years. This update may take the form of a second CRA, or it could be a more limited focus group or half-day, high-level risk analysis. The decision on the type of follow-up is based on the type of project and the significance of the risks identified in the initial evaluation.

FHWA Analysis Required for "Major Projects"

Soltani notes that the financial analysis required for projects considered "Major Projects" under SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users) is similar to the analysis conducted by NDOT for its major projects. In the SAFETEA-LU legislation, Congress required FHWA to conduct a quantitative analysis of the cost estimates provided by state DOTs for Major Projects. Major Projects under this rule include projects:

- With a total cost exceeding $500 million.
- With high visibility.
- Receiving Transportation Infrastructure Finance and Innovation Act credit assistance.

Agencies with projects subject to this requirement must submit project management and financial plans to FHWA. Financial plans are required prior to construction approval and annually thereafter. An FHWA publication (see Related Resources) describes how the financial plan is used:

> Carrying out a Federally legislated mandate, FHWA's Project Delivery Team uses a risk-based probabilistic approach to ensure that State-developed cost estimates are reasonable and supportable. The team provides guidance and educational materials supporting this approach, resulting in a quantified list of project risks and opportunities. The overall cost estimate is expressed as a range, based on the probability that the costs will not exceed a certain dollar amount. A range, rather than a single number, is particularly appropriate early in the project development process when key variables have not been completely defined.

Soltani indicates that NDOT has asked FHWA to certify the agency's risk management process, which uses a probabilistic assessment similar to the approach taken by FHWA. If certified, NDOT would no longer be required to supply FHWA with its financial plan for Major Projects—before construction and annually thereafter—provided NDOT continues to update its own financial plans in accordance with its current practices (NDOT conducts a CRA annually to update project finances at the program level).

Other Tools: NDOT Cost Estimating Wizard

In 2007, a group of smaller projects became the first in NDOT to use a spreadsheet-based tool—the NDOT Cost Estimating Wizard—to bring consistency to the cost estimating conducted within the agency and by local agencies working with NDOT to deliver their projects. Used when projects are in the planning phase and up to the point at which the project is 30 percent designed, this consultant-developed tool allows the estimator to enter general project parameters (project length, area and type of bridge, etc.) and apply estimated quantities and average recent NDOT unit prices to arrive at a cost estimate.

The tool's Estimate Preparation Assistant guides the user through a process to gather and enter information needed to generate a cost estimate at the earliest phase of a project. Behind-the-scenes data include cost and quantity information that is managed by the NDOT administrator. Costs are taken from average unit price data for NDOT pay items that has been compiled from recent bids on NDOT projects. A separate software program is used to update this cost information, typically quarterly. Estimated quantities are also populated behind the scenes, with this data representing typical NDOT sections.

In addition to generating the total construction cost, the tool also identifies engineering design, administrative and legal costs, right of way and environmental mitigation. The tool makes it easy for users to generate multiple estimates to compare different scenarios.

Risk Management Program Impacts

Soltani highlights cost savings related to Project Neon, a 20-year program of improvements in the heart of Las Vegas, as an example of risk management impacts. After initiating a quantitative risk assessment, the project's initial cost estimate was reduced by approximately $500 million.

Recommendations for Success

NDOT has no dedicated staff to support its risk management activities. Soltani recommends development of an internal support team within the agency that has the staff and training to conduct and support risk management activities.

Developing a quantitative risk management strategy requires expertise in cost estimation, risk management and economics. Soltani recommends ensuring staff understand the probabilistic modeling used in a quantitative risk analysis.

Undertaking a quantitative effort to analyze risk in the project development process may require a significant culture change. Training is important to encourage staff to move beyond traditional cost-estimating practices.

Related Resources

Risk Management and Risk-Based Cost Estimation Guidelines, Nevada Department of Transportation, August 2012.
https://www.nevadadot.com/uploadedFiles/NDOT/Documents/RBE_Guidelines_Final_2012_August.pdf
This report provides information about the CRAs NDOT conducts for its major and innovative delivery projects. A table on page 4 of the guidelines (page 20 of the PDF) identifies the type of assessment recommended for NDOT projects based on project size; see below for a representation of this table.

Project Size	Required Process	Suggested Process
< $10 million	Qualitative assessment	Qualitative assessment
$10 million to $25 million	Qualitative assessment	Informal quantitative workshop using the NDOT Risk Tracking and Analysis Tool for Small and Medium Size Projects
$24 million to $100 million	Qualitative assessment	Cost Risk Assessment (CRA)
> $100 million	Cost Risk Assessment (CRA)	N/A

US 95 Northwest Corridor Phases 2, 3, and 5 Cost Risk Assessment Update; Final Report, Ken Smith, John Stout, Blane Long and Michael Ameen, Nevada Department of Transportation, August 2014.
See Attachment A.
This CRA report identifies the overall objective of the CRA workshop as "quantify[ing] uncertainty and risk in the project cost and schedule for the project." Other objectives include:

- Develop a common understanding among participants of the CRA as well as the project, including project characteristics, schedule, costs and risk issues.
- Review and validate the base cost estimate for each phase.
- Quantify uncertainty in quantities and unit bid prices surrounding the base cost estimate for each phase.
- Review and validate the project schedule.
- Identify and quantify cost and schedule risks for each phase.

Cost Risk Assessment: Interstate 15 South Corridor Improvements, Sloan Road to Tropicana Avenue, Clark County, Nevada, Nevada Department of Transportation, June 2014.
See Attachment B.
This report includes an example of a Risk Summary Sheet, which "provides all of the information for an individual risk on a single page." The summary sheet includes a "Heat" diagram that shows a correlation between probability and impact for an individual risk.

Project Development and Scoping Guidelines—Linking Planning and NEPA: Project-Level Scoping, Nevada Department of Transportation, October 2009.
See Attachment C.
Page E-5 of these guidelines (page 110 of the PDF) describes the NDOT Cost Estimating Wizard.

Project Delivery: An Introduction, Office of Innovative Program Delivery, Federal Highway Administration.
http://www.fhwa.dot.gov/ipd/pdfs/fact_sheets/program_project_delivery_introduction.pdf
This web site describes the requirements associated with Major Projects as defined by a federally legislated mandate, including a risk-based probabilistic assessment of state DOT cost estimates.

Note: The citation above also appears later in this Preliminary Investigation with other documents describing FHWA's risk-based probabilistic assessment of state DOT cost estimates; see page 29 of this Preliminary Investigation for more information.

"NDOT Major Projects & Pioneer Program," Amir M. Soltani, Nevada Department of Transportation, June 18, 2014.
See Attachment D.
This presentation, given to FHWA, includes a discussion of NDOT's risk management practices (see slide 40 of the presentation).

New York

Contacts: Richard Lee, Acting Director, Office of Design, New York State Department of Transportation, 518-457-5289, rich.lee@dot.ny.gov.

Carlos Rivera, Assistant to Director, Office of Design, New York State Department of Transportation, 518-457-2400, carlos.rivera@dot.ny.gov.

Background

NYSDOT began considering how to formally manage risk during project development in the early 2000s with the development of a design-build manual. After examining practices in other states, NYSDOT prepared a manual that encouraged an assessment of risk as well as an identification of responsible parties, and provided a mechanism to identify and monitor risks (a risk matrix).

By 2008, the risk management guidance applied to design-build projects began to be considered for application to traditional projects. Two 2009 initiatives—the American Recovery and Reinvestment Act of 2009 (ARRA) and New York Works, a New York-specific version of ARRA—prompted NYSDOT to look at risk differently. In 2009, a new risk management guide was developed for a range of projects and project complexities. The guide began as a stand-alone document and is now part of the agency's Project Development Manual. A new version of the 2009 edition of the guide was reintroduced in December 2014 with minor revisions and adopted for broad use within NYSDOT.

Since 2009, NYSDOT has applied quantitative risk assessment during the project development phase of these projects:

- $550 million design-build Kosciuszko Bridge Project in New York City.
- $3.9 billion Tappan Zee bridge replacement project (the Tappan Zee Bridge crosses the Hudson River, connecting South Nyack in Rockland County and Tarrytown in Westchester County).

Quantitative risk management practices were also applied to a project to repair and rebuild Route 9A in the aftermath of the collapse of the World Trade Towers in 2001.

The Process

NYSDOT has limited experience to date with applying quantitative risk management during project development. Projects are more likely to involve the use of a qualitative risk register. When NYSDOT does conduct a quantitative risk assessment, the process is similar to the one used by NDOT, UDOT and WSDOT—consultants lead a one-day or multiday workshop that brings together a range of subject matter experts to identify risks and quantify them using a consultant-supplied risk assessment tool. As other states have indicated, NYSDOT continues to review and update risk registers generated by the initial risk assessment workshop.

Challenges

Richard Lee and Carlos Rivera note that the rapid pace of the procurement process can make it difficult to find time to conduct a risk assessment and then integrate results of the assessment into the procurement document.

Recommendations for Success

The following were highlighted by Lee and Rivera as key to an effective risk management process:

- It is important to get a handle on data, making sure that the many “moving parts” associated with risk management are successfully integrated.
- Striking the right balance of quantifying and managing risk with the most effective use of limited resources can be difficult. Seek a “reasonable equilibrium” to make the best use of risk management practices.

What’s Next

Several years ago NYSDOT launched a new Office of Project Management. With this new office, Lee expects NYSDOT to become more focused on the assessment of risk and adopt more formalized, agencywide risk-related practices. In addition to the Office of Project Management possibly making changes to the recently adopted risk management guide, NYSDOT has been revamping its project manager training and guidebook to reflect risk management practices.

Lee suggests that more may be known about NYSDOT’s adoption of more formalized risk management practices sometime later this fall.

Related Resources

Appendix 15: Risk Management for Project Development, Office of Design, New York State Department of Transportation, April 9, 2009.
https://www.dot.ny.gov/divisions/engineering/design/dqab/dqab-repository/Risk%20Management%20for%20Project%20Development%20Guide_Final%20Draft_010514_0.pdf
This guides focuses mostly on qualitative risk analysis. As the guide indicates, "the majority of risk analysis will be performed for simple and moderate type projects. Complex projects will typically use quantitative methods." NYSDOT's approach to quantitative risk analysis is addressed in Appendix E, which begins on page 65 of the guide (page 74 of the PDF). Appendix E describes the forms a quantitative analysis may take:

> Quantitative risk analysis involves statistical simulations and other techniques from the decision sciences. Tools commonly employed for these analyses include first-order second-moment (FOSM) methods, decision trees, and/or Monte Carlo simulations. The Department's, and FHWA's, de-facto standard tool for performing Monte Carlo simulations is Chrystal Ball.

Utah

Contact: Fred Doehring, Deputy Pre-Construction Engineer, Utah Department of Transportation, 801-633-6215, fdoehring@utah.gov.

Background

More than 10 years ago, in an effort to address problematic issues associated with a large project, UDOT investigated a quantitative risk assessment model used by WSDOT—Cost Estimate Validation Process (CEVP)—eventually hiring a consultant to run the model for UDOT. Four years ago, UDOT management revisited its risk management program and installed Fred Doehring—our interviewee—in his current role overseeing the agency's risk management activities.

The Process

UDOT uses both qualitative and quantitative tools (see below) to assess risk during the project development process, and some form of risk management is applied to every project.

- Smaller projects ($20 million or less): qualitative tool.
- Medium-size projects (between $20 million and $100 million: quantitative Monte Carlo tool developed by UDOT.
- Large projects (more than $100 million): hire a consultant to run a risk workshop that employs the CEVP tool or a similar tool. The typical risk workshop is an eight-hour session.

The risk management model is applied as early as possible in project development. For projects that will involve an environmental assessment (EA) or environmental impact statement, Doehring suggests running two models: the first time at the beginning of the EA process to create a risk registry associated with completing the environmental document, and a second model after the environmental document has been prepared to identify the cost of proposed solutions. All but the smallest projects involve a risk workshop typically conducted by Doehring.

To provide additional staff support, Doehring is preparing videos to help project managers learn how to use the Monte Carlo tool and lead a risk workshop.

When a value engineering study is required, UDOT conducts a risk workshop, runs the quantitative model to identify the highest risks and then focuses value engineering on those particular risks.

The Quantitative Tool

The tool used by consultants to conduct risk assessment for large projects is a more sophisticated version of the Excel-based Monte Carlo tool UDOT uses for medium-size projects (see Related Resources for a link to the Excel-based UDOT tool). The more advanced assessment tool used by consultants examines multiple scenarios, develops decision trees and identifies the impacts of potential actions taken.

The schedule and risk registry generated by the risk workshop are part of the discussion of weekly or biweekly project team meetings and serve as effective tools for monitoring and tracking project risks. The registry includes a responsible party and due date for each risk item, along with the proposed mitigation strategy. The quantitative model can be rerun as needed to demonstrate the impact of a new cost and schedule estimate.

Implementing the Process

UDOT is a decentralized agency with four regions, each responsible for its own design and construction. Integrating new policies at the region level can be challenging. To begin implementation of the risk workshops, Doehring selected one project manager to serve as a pilot for the program. As other project managers in that region started using the tool, word-of-mouth spread among the other regions, and Doehring developed a network of early adopters to help him further implement the program. At this time, Doehring estimates that 80 to 90 percent of project managers use the risk management tools on a regular basis. The tools are also made available to consultants working on projects for the agency.

Risk Management Program Impacts

Doehring notes that the benefits of quantitative risk management go beyond the charts and graphs produced by the tools, and cites the significance of the communication that occurs during the risk workshops. Bringing people together in the risk workshops has helped UDOT bridge gaps between “cylinders of excellence” in the agency.

Recommendations for Success

Noting that it took about three years to achieve broad acceptance for the risk management program, Doehring advises other agencies to “be patient and start small.” Doehring also highlights the need for a good facilitator. Risk workshops are only effective if those present participate, and spurring conversation is critical. An experienced engineer—like Doehring—who is familiar with the types of risks encountered during project development and construction, and is also comfortable with engaging staff and encouraging discussion, has the potential to be a good facilitator.

What's Next

UDOT is investigating an expansion of its risk management practices into a project's construction phase, using the risk registry developed during the design phase as a basis for developing a collaborative risk management process with the contractor. This approach would identify risks from UDOT's perspective and then get feedback from the contractor who will be participating in construction. The end goal of this process is the development of mitigation strategies that both parties can agree on to address issues that may arise in the field during construction. Doehring hopes to have the new practice in place for next year's construction season.

Related Resources

"Project Level Risk Management at UDOT: How UDOT is Incorporating ERM into Its Project Delivery Process," Utah Department of Transportation, May 18, 2015.
http://www.udot.utah.gov/main/uconowner.gf?n=12333427762129187
This presentation provides a high-level examination of UDOT's risk management processes.

"Risk 101: The Basics of Risk Management, Part 1," UDOT University, Utah Department of Transportation, May 18, 2015.
http://connect.udot.utah.gov/risk101pt1/
This is the first part of an instructor-led training session on UDOT's approach to managing risk.

"Risk 101: The Basics of Risk Management, Part 2," UDOT University, Utah Department of Transportation, May 18, 2015.
http://connect.udot.utah.gov/risk101pt2/
This is a continuation of the risk training session cited above.

"Risk 102: Choosing Wisely—Picking the Right Risk Tool to Use on Your Project," UDOT University, Utah Department of Transportation, May 18, 2015.
http://connect.udot.utah.gov/p5ntje0ptb4/
This training session highlights the decision tree that staff uses to select the most appropriate tool for a risk assessment.

UDOT Risk Model for Monte Carlo Analysis (Excel), Utah Department of Transportation, November 18, 2014.
http://www.udot.utah.gov/main/uconowner.gf?n=18477703684179398
This is the quantitative risk assessment tool UDOT has developed for use on its medium-size projects.

Virginia

Contacts: Bruce E. McAuliffe, Assistant Director, Project Management Office, Virginia Department of Transportation, 804-786-6757, bruce.mcauliffe@vdot.virginia.gov.

Jeffrey Cutright, Director, Project Management Office, Virginia Department of Transportation, 804-225-4958, jeffrey.cutright@vdot.virginia.gov.

Bruce McAuliffe, assistant director of Virginia DOT's Project Management Office, indicated in his response to our email inquiry that the agency applied a risk evaluation matrix to specified projects. We spoke with McAuliffe and his colleague, Jeffrey Cutright, to learn more about this process and the possible application of quantitative risk management practices at VDOT.

Background

A recently adopted Project Management Procedure requires VDOT to apply project risk management practices to all Tier II projects (large projects, design-build projects, and all federal oversight and nonfederal oversight projects having construction values greater than $5 million). A qualitative Risk Analysis Matrix identifies the probability and impact of anticipated risks and potential responses to each risk. Risks are examined and reassessed at each of the project development phase milestones, and the matrix is updated as appropriate.

The agency's use of quantitative risk management practices during project development is limited to public-private partnership projects. A description of the agency's approach to quantitative risk assessment for this type of project appears in *Virginia Public-Private Partnerships: P3 Risk Management Guidelines* (see Related Resources).

Related Resources

Project Risk Management, Project Management Procedure PMO-15.0, Virginia Department of Transportation, February 1, 2015.
http://www.virginiadot.org/business/resources/LocDes/Risk_Management_PMO-15.pdf
This procedure sets out the requirements for VDOT's approach to project risk management for Tier II projects.

Virginia Public-Private Partnerships: P3 Risk Management Guidelines, The Commonwealth of Virginia, March 2015.
http://www.p3virginia.org/wp-content/uploads/2015/03/Risk-Management-Guidelines_3.20.2015.pdf
Appendix D, which begins on page 36 of the guidelines, provides an example of a risk register and how it is used in expected value and Monte Carlo quantitative analyses. Appendix F (see page 43) provides a more in-depth view of a Monte Carlo analysis, with examples of program outputs.

Washington

Contact: Mark Gabel, Cost Risk Estimating Manager, Washington State Department of Transportation, 360-705-7457, gabelm@wsdot.wa.gov.

Background

WSDOT began developing CEVP in 2002. WSDOT's CEVP team included Golder Associates, a consulting, design and construction services firm, which developed the initial tool used in CEVP workshops for large projects and the CRA used for smaller projects or projects that are not complex enough to warrant the more intensive CEVP. The first CEVP workshops were held in 2003, and at that time WSDOT also began to address risk associated with lower-level construction efforts with CRA workshops. In 2005, WSDOT established a statewide policy for cost risk assessment, including use of CRAs and CEVPs. As Mark Gabel notes, WSDOT's risk management tools are scalable and cover a broad spectrum, allowing project managers to select the most appropriate tool.

The Process

The table below summarizes WSDOT's tiered risk assessment process. The table is taken from WSDOT's November 2014 *Project Risk Management Guide* (page 20 of the PDF). See Related Resources for a link to this guide.

Project Size ($M)	Required Process*
Less than $10M	Qualitative spreadsheet in the *Project Management Online Guide*[1]
$10M to $25M	Informal workshop using the self-modeling spreadsheet[1][3]
$25M to $100M	Cost Risk Assessment (CRA) workshop[1][2]
Greater than $100M	Cost Estimate Validation Process® (CEVP®) workshop[2]

[1] In some cases, it is acceptable to combine a Value Engineering Study with a Risk-Based Estimating Workshop.

[2] Projects $25 million and over should use the self-modeling spreadsheet in the scoping phase of the risk-based estimating process, followed up by the more formal CRA or CEVP® process during the design phase.

[3] An informal workshop is composed of the project team (or key project team members); other participants may be included as the Project Manager/project team deem necessary.

*Project Managers can use a higher-level process if desired.

The Workshops

Staffing the CRA workshops has evolved over the years, with early CRAs almost always conducted by consultants. Today, CRA workshops are typically conducted in-house by Gabel or his colleagues. Gabel notes that project managers are typically too busy to lead the workshops, and WSDOT prefers benefiting from the specialized expertise of individuals trained to conduct the workshops. Some CRAs use blended teams that include a consultant and in-house staff

person. Gabel notes that consultants are particularly useful to lead the risk assessment process for larger projects that are politically charged or in cases when an external partner has expressed interest in a risk analysis led by someone outside the agency.

A CEVP begins with a request form submitted by the project manager to Gabel's office. The following are key elements of a CEVP workshop:

- The workshop unfolds over three to five days after one or two prep sessions.
- Workshops can be conducted in-house but are often conducted by consultants.
- Two consultants (a project lead and one support person) oversee each consultant-led workshop.
- One external subject matter expert addresses construction-related issues. This is often an individual who has retired from a local construction firm with significant experience in the field. This individual cannot be affiliated with a contractor who may be bidding on the project.
- One subject matter expert provides construction cost-estimating experience. This individual is typically someone who has developed cost estimates for consultants. WSDOT maintains a Consultant Services web site that identifies individuals who can be selected for this task.
- Other specialists may be required depending on the project (for example, mechanical engineers or queuing specialists for ferry work).

For very large projects or programs—with a cost of $1 billion or more—WSDOT may work with consultants to continue to update the workshops. For a large program of multiple projects, the agency may split out the smaller projects for an in-house workshop and model, while larger components are addressed by a consultant.

The Quantitative Tool

Both the CRA and CEVP use project simulation that applies "the Monte Carlo technique to generate a probability distribution of project cost and schedule based on uncertainty and risk effects." Consultants leading workshops will typically apply their own Monte Carlo tool. WSDOT's own Monte Carlo model includes two dozen risks in the tool's self-modeling spreadsheet (see Related Resources for more information about this tool). A project manager could complete this model independently.

One of the key outputs of quantitative risk assessment is a risk register. Development of the register begins with identification of risks prior to and during the workshop phase. As the risk management process unfolds, the register is developed further to provide a prioritized list of quantified risks. The description of risks that have the most impact on project objectives can take the form of tornado diagrams, expected values and decision trees. The output of the Monte Carlo probabilistic analysis provides estimated costs and completion dates with their associated confidence levels.

Implementing the Process

Gabel suggests bringing in qualified consultants when launching a quantitative risk assessment program. Agencies may also wish to consider seeking guidance from risk assessment experts outside the transportation industry, such as analysts with experience in risk assessment as it relates to the secondary insurance market.

Risk Management Program Impacts

Like others we spoke to for this Preliminary Investigation, Gabel notes that it is difficult to quantify the benefits of quantitative risk management. Anecdotally, Gabel indicates that quantitative risk management results in better cost estimates and establishes risk reserves, and better equips project managers to address issues that arise in the field. And, as Gabel suggests, if risk management did not pay off, why is it an integral part of every project management process?

Challenges

Gabel highlighted these challenges associated with implementing a comprehensive risk management process during project development:

- Initially, Gabel recognized some skepticism among staff about the process, and some staff members felt protective of their cost estimates.
- Agencies without an existing project management process may find that staff is more reluctant to accept risk management practices.
- Risk registers can become too cumbersome when they include 50 to 100 items. Not everything has to be assessed using a quantitative model. The focus should be on identifying the significant risks that can affect project objectives (schedule and budget).
- Most software programs used in quantitative risk assessment employ expected value (probability × impact) to rank risks. In practice, this means that a $500 million risk with a 2 percent probability, which results in a $10 million risk, will rank in the same place in a risk register as a $20 million risk with a 50 percent probability.

  Gabel notes that this can be misleading, and the project team may fail to pay adequate attention to the $500 million risk. In this example, and in many others, the impact can be much more important than the probability. WSDOT's *Project Risk Management Guide* refers to high-impact, low-probability risks as "black swan" events and indicates that these events can devastate a project.
- It is important to stay the course. Not every CRA or CEVP will have the results expected. Gabel notes that it take two to three years to earn staff confidence and demonstrate competence in the process.

Recommendations for Success

Noting that WSDOT's understanding of the quantitative risk management process grew exponentially between 2002 and 2010, Gabel shared these recommendations for other agencies implementing a quantitative risk management process during project development:

- Executive and management support is necessary. For WSDOT, interest in CEVP started with the department secretary.

- The agency had a strong project management process that included directives to identify risks even before introducing a formal risk management program.
- Project managers who are engaged and embrace the philosophy of risk management can encourage successful implementation across the agency.
- At WSDOT, five staff members (now three) were trained in risk management principles and the tools available to conduct risk assessment such as the Monte Carlo assessments WSDOT uses today. Gabel cautions agencies against shortchanging the philosophical assessment of risk management in favor of focusing solely on tools.

Related Resources

Project Risk Management Guide, Engineering and Regional Operations, Washington State Department of Transportation, November 2014.
http://www.wsdot.wa.gov/publications/fulltext/cevp/ProjectRiskManagement.pdf
Sections of this guide that may be of particular interest include:

- Chapter 4, Quantitative Risk Analysis, which begins on page 43 of the PDF.
- Part II: Guidelines for CRA-CEVP® Workshops, which begins on page 73 of the PDF.

Cost Risk Assessment (CRA) and CEVP®, Washington State Department of Transportation, 2015.
http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/
This web site provides access to a wealth of resources related to WSDOT's risk management activities. Some of the resources available on this site are highlighted in the citations that follow.

Managing Cost and Schedule—CEVP and Risk Management, Washington State Department of Transportation, undated.
http://www.wsdot.wa.gov/NR/rdonlyres/198E080B-9EB0-4787-8434-13475336ED85/0/CEVPPoster.pdf
This poster provides a brief history of WSDOT's use of a cost estimate validation process, how the process works and its impacts.

Risk Management Plan Spreadsheet, Washington State Department of Transportation, undated.
http://www.wsdot.wa.gov/publications/fulltext/cevp/RiskManagementPlan.xls
A user guide included in this Excel-based spreadsheet tool describes what is captured in the spreadsheet:

- Risk identification (the eight column sections of the spreadsheet).
- Qualitative risk analysis (depicted with the risk matrix red-yellow-green chart).
- Quantitative risk analysis (captured in four column sections following risk identification).
- Risk response (strategy (avoid/transfer/mitigate/accept) and action to be taken).
- Risk monitoring and control (who owns the risk and will track the response to it).

Risk Based Estimate Self-Modeling (RBES), Washington State Department of Transportation, undated.
http://www.wsdot.wa.gov/publications/fulltext/CEVP/Short%20Description%20RBES.doc
This document provides instructions for use of an Excel-based self-modeling risk assessment spreadsheet developed by WSDOT. From the document:

> The RBES is an open code tool, designed to facilitate the integration of the cost and schedule estimate of projects by performing quantitative risk analyses. The model is capable of capturing, analyzing, and displaying the simulation results of "premitigated" and "postmitigated" scenarios on the same graph.
> ….
> The essential part of the cost/schedule risk assessment process is separating risks from the base cost and then quantitatively expressing them in: impact strength and probability of occurrence. The maximum number of risks to consider is 24.

Related Resource:

> **Project Risk Management Plan Spreadsheet (RMP)**, Washington State Department of Transportation, undated.
> http://www.wsdot.wa.gov/publications/fulltext/CEVP/RBE-WEB.xlsm
> This link provides access to the Excel-based self-modeling tool. The final spreadsheet in this workbook contains a brief user's guide.

Project Management Online Guide: Pre-Construction, Washington State Department of Transportation, 2015.
http://www.wsdot.wa.gov/Projects/ProjectMgmt/PMOG.htm
This online guide includes links to more information about risk-related processes throughout the pre-construction phases of project development.

Other State DOT Quantitative Risk Management Practices

In this section, we supplement the consultations with select state DOTs with publications that describe, to varying degrees, how three other state DOTs—Florida, Montana and Ohio—use quantitative risk management practices during project development.

Florida

"Risk Analysis/Management during Project Development," Phillip "Greg" Davis, Florida Department of Transportation, *Ohio Planning Conference*, July 16, 2014. http://www.dot.state.oh.us/Divisions/Planning/Conference/Documents/Presentations/Wednesday-July-16/5-D/Davis_Session5D.pdf
This presentation provides a high-level description of FDOT's risk management process. Some highlights:

- *Risk analysis workshops*. These two- to-three-day structured events provide an opportunity for a team of participants to "identify and quantify threats and opportunities" and "identify risk management strategies." Workshop participants include the project manager and the design team, external subject matter experts, and other internal and external stakeholders. Modeling is used to analyze project risks and develop a baseline risk assessment.
- *Project team contribution*. The project team offers an initial cost estimate and backup estimate, a schedule for design and construction, and a list of risks that may have been informed by a "risk starter list" (see slide 15 of the presentation for FDOT's risk starter list).
- *Workshop deliverables*. Results of the workshop include a final report and risk register for project manager use in the ongoing monitoring of risks.
- *FDOT staff involvement*. A Statewide Risk Management Team is supported by Regional Risk Management Teams.
- *Levels of risk analysis*. Slide 26 of the presentation identifies the types of risk analysis conducted by FDOT:
    - Complex project or total project cost greater than $500 million—consultant-led independent risk analysis workshop.
    - Total project cost between $100 and $500 million—risk analysis workshop using commercial risk modeling program.
    - Projects not requiring a formal workshop—risk analysis modeling tool developed by HDR, Inc.

"Risk Analysis Process Training for Project Managers," Greg Davis, Kurt Lieblong and Alan Autry, Florida Department of Transportation, *2014 Design Training Expo*, 2014. http://www.dot.state.fl.us/officeofdesign/Training/DesignExpo/2014/presentations/CRATeam-RiskAnalysisProcessTraining.pdf.
This training presentation includes three sections: introduction and pre-workshop activities (similar to the presentation cited above), risk analysis workshop and project case studies.

"Risk Analysis Process Training," Greg Davis, Kurt Lieblong and Rob Quigley, Florida Department of Transportation, *2012 Design Training Expo*, 2012.
http://www.dot.state.fl.us/officeofdesign/training/designexpo/2012/Presentations/CRA%20Team%20-%20Risk%20Analysis%20Process%20-%20presented.pdf
This training presentation includes three sections: risk analysis process overview (similar to the two presentations cited above), risk analysis workshop and project manager roles.

Scope of Services: Statewide Cost Risk Workshop and Analysis Services, Florida Department of Transportation, February 9, 2015 (date of advertisement).
http://www2.dot.state.fl.us/procurement/ProfessionalServices/advertise/pdf/15911.pdf
This request for professional services seeks a contractor "to provide risk management services related to transportation facilities and to conduct training in the principles of risk management." The scope of services describes the activities a contractor is expected to engage in to support the agency's cost risk workshop and analysis activities.

Cost Risk Assessment Final Report: State Road 826/Palmetto Expressway from SR 836/Dolphin Expressway to State Road 932/NW 103 St, PMA Consultants LLC and Florida Department of Transportation, July 9, 2012.
http://www.palmettoexpresslanes.com/system/pdfgallery/palmetto_pde_study/Cost%20Risk%20Assessment%20Final%20Report%20July%202012.pdf
This final report documents the results of a 2012 risk assessment workshop conducted in advance of a value engineering study for FDOT's SR 826 Managed Lanes Project. A description of results of the workshop begins on page 17 of the report.

Chapter 19—Risk Management, *Project Management Handbook, Part 1: Issues Common to All Project Managers*, Florida Department of Transportation, March 4, 2008.
http://www.dot.state.fl.us/projectmanagementoffice/PMHandbook/P1_Ch19.pdf
This chapter of Part 1 of FDOT's Project Management Handbook provides a theoretical assessment of when a quantitative risk analysis could be used (see page 11 of the PDF). The manual does not provide details of FDOT's current risk analysis practices.

Montana

Risk Management Guidelines: Managing Project Costs through Identification and Management of Risks, Draft, Montana Department of Transportation, January 2014.
http://www.mdt.mt.gov/other/roaddesign/external/report_templates_guidance/risk_manual_mdt_draft.pdf
From page 11 of the guidelines:

> This guidance introduces a new policy for MDT cost estimators to include risk management in their estimating and design project management. The level of analysis will be commensurate with the complexity of the project. In general, the following level of risk management is required for MDT projects. These requirements are a minimum; project managers can use a higher level of analysis as appropriate for individual projects.

Project size (CN)	Required process	Level of analysis
< $1 M (Minor)	Risk identification	Informal
< $20 M (Moderate)	Qualitative risk analysis	Informal with or without team
> $20 M (Complex)	Quantitative risk analysis	Informal workshop with team
Very complex/major	Cost Risk Assessment	Formal workshop
Note that the Cost Risk Assessment results can be used in Value Analysis (VA) studies, and that VA studies may identify additional risks. *Informal analysis can be completed by an individual project manager or with design team members.* *Formal analysis should include design team members as well as other experts with construction and cost-estimating experience appropriate for the project.*		

Based on data from the last five years, the majority of MDT projects will qualify for the informal qualitative risk analysis or risk identification alone. Very few of the projects under design should have an informal quantitative risk analysis with a team. In rare cases, a formal Cost Risk Assessment workshop should be considered. Factors to consider when determining the level of risk analysis and management effort include:

- Political sensitivity
- Type and complexity of project
- Location of project and the community it serves
- Project duration
- Stakeholder involvement
- Project delivery method selected

Any of these factors may warrant the use of a higher level of analysis.

Ohio

"Cost Estimate Reviews for Ohio's Major Projects," Jason P. Spilak, Ohio Department of Transportation, *ODOT Planning Conference*, July 16, 2014.
http://www.dot.state.oh.us/Divisions/Planning/Conference/Documents/Presentations/Wednesday-July-16/5-D/Spilak_Session5D.pdf
This presentation describes Ohio DOT's new approach to addressing project risk. The agency's first cost estimate review (CER) was conducted in 2013, and a second CER was planned for the fall of 2014. Other candidate projects were expected to be considered for a CER during winter/spring 2015.

The presentation compares ODOT practices to FHWA's requirements for Major Projects, noting that ODOT's CER process "follows FHWA CER very closely." FHWA provides technical expertise and guidance, and subject matter experts from within ODOT and the consultant community participate in the process.

Estimates resulting from the process, as described on slide 8, include:

- Present-day estimate.
- 70 percent confidence (present day) estimate (using Oracle Crystal Ball software to perform Monte Carlo simulations).
- 70 percent year of expenditure estimate (incorporating inflation forecasts to year of expenditure).

Domestic Research and Resources

Completed Research

Guide for the Process of Managing Risk on Rapid Renewal Projects, Golder Associates Inc., Keith Molenaar, Michael Loulakis and Ted Ferragut**,** SHRP 2 Report S2-R09-RW-2, July 2014.
http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R09-RW-2.pdf
This guide "provide[s] tools that transportation agencies can use to apply risk management principles systematically to their projects. They are specifically useful for those projects that are below the $500 million threshold for major projects." Of particular interest is Chapter 7, Risk Management, which begins on page 67 of the guide (page 81 of the PDF).

Risk Assessment for Public-Private Partnerships, Innovative Program Delivery, Federal Highway Administration, December 2012.
http://www.fhwa.dot.gov/ipd/pdfs/p3/p3_risk_assessment_primer_122612.pdf
A discussion of quantitative risk analysis begins on page 26 of the PDF. Two quantitative approaches are examined:

- *Formula-based analysis*. A simple formula is used to calculate average risk impact using minimum, maximum and most likely cost and schedule impacts.
- *Monte Carlo simulation*. Specialized software simulates expected cost and schedule impacts to identify a range of aggregate risk values and their probabilities.

Expedited Planning and Environmental Review of Highway Projects, Parametrix, Inc. and Venner Consulting, SHRP 2 Report S2-C19-RR-1, 2012.
http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-C19-RR-1.pdf
Included in this report is a discussion of risk management, one of 24 strategies identified for addressing or avoiding project constraints.

Volume 1: Guide for Managing NEPA-Related and Other Risks in Project Delivery*, NCHRP Web-Only Document 183: Guidance for Managing NEPA-Related and Other Risks in Project Delivery*, Parsons Brinckerhoff, Inc., October 2011.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_W183v1.pdf
A discussion of a risk framework that includes quantitative assessment begins on page 8 of the report (page 13 of the PDF).

Executive Strategies for Risk Management by State Departments of Transportation, NCHRP Project 20-24(74), Janet D'Ignazio, Matthew Hallowell and Keith Molenaar, May 2011.
http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-24(74)_ResearchReport.pdf
Although most of the focus is on enterprise risk management, this report also addresses tools and techniques implemented to manage program and project risks. See Chapter 3, General Risk Management Strategies, which begins on page 6 of the report (page 20 of the PDF).

NCHRP Report 658: Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs, Keith Molenaar, Stuart Anderson and Cliff Schexnayder, June 2010.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_658.pdf
From the foreword:

> This guidebook provides guidance to state departments of transportation for using specific, practical, and risk-related management practices and analysis tools for managing and controlling transportation project costs. Containing a toolbox for agencies to use in selecting the appropriate strategies, methods and tools to apply in meeting their cost-estimation and cost-control objectives, this guidebook should be of immediate use to practitioners that are accountable for the accuracy and reliability of cost estimates during planning, priority programming and preconstruction.

Related Resource:

> **Cost Estimating and Cost Management Capacity Building Workshop; Proceedings**, Center for Transportation Studies, University of Minnesota, August 2010.
> http://www.cts.umn.edu/Publications/ResearchReports/pdfdownload.pl?id=1442
> In presenting highlights from *NCHRP Report 658: Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs,* Keith Molenaar, a workshop participant, described three quantitative risk assessment tools—expected value methods, three-point estimate methods and Monte Carlo simulation. All three combine spreadsheet and software modeling tools.

NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction, Stuart Anderson, Keith Molenaar and Cliff Schexnayder, November 2006.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_574.pdf
From the foreword:

> This guidebook presents approaches to cost estimation and management to overcome the root causes of cost escalation and to support the development of consistent and accurate project estimates through all phases of the development process, from long-range planning, through priority programming, and through project design.

See page A-134 of the report (page 248 of the PDF) for a discussion of complexity definitions used by MnDOT in its 2008 technical reference manual describing when to apply quantitative risk analysis.

Project Delivery: An Introduction, Innovative Program Delivery, Federal Highway Administration.
http://www.fhwa.dot.gov/ipd/pdfs/fact_sheets/program_project_delivery_introduction.pdf
This summary describes how FHWA's Project Delivery Team employs a "risk-based probabilistic approach to ensure that State-developed cost estimates are reasonable and supportable" for those projects that are classified by FHWA as Major Projects.

Related Resources:

Portsmouth Bypass FHWA Cost Estimate Review, Federal Highway Administration, Ohio Department of Transportation and Atkins, May 2011.
https://www.dot.state.oh.us/Divisions/InnovativeDelivery/Portsmouth/Cost%20Estimate%20Final%20Report%20052011.pdf
This report provides an example of the type of report that is produced after a cost estimate review conducted by FHWA in connection with a project classified by FHWA as a Major Project.

"'Crystal Ball' Risk Based Cost Estimating," Peter Clogston, *Ohio Transportation Engineers Conference*, 2012.
https://www.dot.state.oh.us/engineering/OTEC/2012%20Presentations/08B-Clogston.pdf
This presentation by an FHWA project manager describes the software program FHWA uses to conduct its probabilistic analyses of Major Projects. The presentation closes with an example of the tool's use on a specific bridge project.

Project in Process

"Managing Risk Across the Enterprise: A Guidebook for State Departments of Transportation," NCHRP Project 08-93, expected completion date: October 17, 2015.
Citation at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3635
From the abstract:

> The objective of this research is to produce a guidebook for state DOTs that (1) provides a comprehensive framework to identify and manage risk and (2) identifies available tools, and develops new tools where appropriate, that agencies might find useful in identifying and managing risk. The guidebook will (1) assist state DOTs in planning, staffing, implementing and evaluating consistent and effective risk management functions, (2) demonstrate the benefit and strategic value of enterprise risk management to executive and senior staff, and (3) build on the findings of previous research and international scan findings.

International Research and Resources

"Risk Based Cost Estimation of Capital Intensive Road Projects Using Monte-Carlo Simulation," Mahender Rao and Harshavardhan V. Ranade, *IPWEA International Public Works Conference*, August 2013.
http://trid.trb.org/view.aspx?id=1265351
From the abstract:

> This paper presents the application and validation of a new and innovative tool developed for accurate risk based estimation of project budgets. Typical capital intensive projects to which this tool can be applied include road reconstruction, road resheet and road rehabilitation projects. Quantitative risk analysis and stochastic modeling using Monte-Carlo Simulation is embedded in the algorithms of the computer code. The tool forecasts a range of possible project costs and the probability of the occurrence of those costs by taking into account uncertainties and associated risks. Application of the tool to capital intensive road projects designed by Harsha Ranade and constructed in 2011 & 2012 demonstrates the validity, usefulness and benefit of the proposed tool. Comparisons of forecasted estimates using this new tool with actual costs and with traditional deterministic methods of cost estimation (such as single-point base-case estimates inclusive of contingency) provide valuable insights that can aid management in evaluating alternatives and make informed decisions when estimating and allocating budgets to a portfolio of road projects.

Transportation Risk Management: International Practices for Program Development and Project Delivery, Joyce A. Curtis, Joseph S. Dailey, Daniel D'Angelo, Steven D. DeWitt, Michael J. Graf, Timothy A. Henkel, John B. Miller, John C. Milton, Keith R. Molenaar, Darrell M. Richardson and Robert E. Rocco, International Technology Scanning Program, Federal Highway Administration and American Association of State Highway and Transportation Officials, August 2012.
http://www.trafi.fi/filebank/a/1434375830/62ed215023d877e74c662e1a437be266/17838-LIITE_D_Fed_Highway_Admin_full_report_2012.pdf
This scanning study of Australia and Europe "documented risk management policies, practices, and strategies for potential application in the United States." Points of interest include:

- Structures for successful risk management (page 13 of the report; page 25 of the PDF).
- Risk registers (page 14 of the report; page 26 of the PDF).

"'Best Practice' Cost Estimation in Land Transport Infrastructure Projects," Fiona Tan and Tariro Makwasha, *Proceedings of the Australasian Transport Research Forum*, 2010.
http://atrf.info/papers/2010/2010_tan_makwasha.pdf
From the abstract:

> This paper introduces the element of risk in the cost estimation of land transport infrastructure projects. The paper is structured on the recommendations from the Evans and Peck (2008a) report on 'Best Practice Cost Estimation for Publicly Funded Road and Rail Construction' undertaken and adopted by the Department of Infrastructure, Transport, Regional Development and Local Government (DITRDLG). The essentials of risk analysis are provided, including several issues encountered by practitioners. A comparison of the P50 versus P90 cost estimation, including discussions on how to deal with the current practice of pricing contingencies in project cost estimation is undertaken. With the use of a generic project example, an empirical application of the P50 and P90 cost estimation is demonstrated. This paper is intended to draw the attention of transport agencies to the Best

Practice Cost Estimation ('the Standard') in the preparation of cost estimates for any proposed project(s) that require funding from the Australian Government.

Practice Standard for Project Risk Management, Project Management Institute, July 2009.
Product description at
http://marketplace.pmi.org/Pages/ProductDetail.aspx?GMProduct=00101169201
From the description:

> Written for project managers, project team members, supervisors and stakeholders, the *Practice Standard for Project Risk Management* outlines the principles of effective risk management:
>
> - Plan Risk Management
> - Identify Risks
> - Perform Qualitative Risk Analysis
> - Perform Quantitative Risk Analysis
> - Plan Risk Responses
> - Monitor and Control Risks

"Risk-Based Cost and Schedule Estimation for Large Transportation Projects," M.L.J. Maher and A.D. McGoey-Smith, *2006 Annual European Transport Conference*, September 2006.
http://web.mit.edu/11.951/oldstuff/albacete/Other_Documents/Europe%20Transport%20Conference/innovative_transport_i/riskbased_cost_and1510.pdf
From the introduction to the conference paper:

> During the last three years the authors have been involved in promoting and delivering Golder's QPRA [Quantitative Project Risk Assessment] services to large transportation projects in Canada. At present there is a large amount of transportation infrastructure either planned or underway in Canada in both urban environments such as depicted in the first photograph but also in rural environments as depicted in the second photograph. Road construction in both of these environments faces different challenges; the QPRA process presented in this paper is quite general. It is flexible enough to be applicable to both environments. The authors believe that Golder's QPRA process would be beneficial to managing infrastructure projects in Europe[an] too. …
>
> Golder's QPRA was developed a few years ago by William J Roberds and co-workers of Golder Associates, Seattle, WA, USA at the request of Washington State Department of Transportation. … In this paper we describe the QPRA process from the perspective of transportation engineers and planners and illustrate the method using results from a recent QPRA of a major highway expansion project in western Canada.

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