



Quantifying Right of Way–Related Risks Using Cost Estimating and Risk Management Tools: Survey of State Practice

Requested by
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Executive Summary

Background

The Caltrans Division of Project Management has developed an Excel-based risk tool that estimates support and capital risk-related costs and schedule impacts through all phases of project development. To identify the most effective inputs for this tool, the Caltrans Division of Right of Way and Land Surveys is seeking information from other state departments of transportation (DOTs) regarding their use of cost estimating and risk management tools, as well as tool inputs specifically related to right of way (ROW). Of particular interest is the program evaluation and review technique (PERT), an estimating technique that employs a weighted average of three values to obtain a final estimate.

To inform Caltrans' use of appropriate inputs for its risk tool, CTC & Associates conducted a survey of 14 state DOTs known to have experience with quantitative cost estimating or risk management tools. Findings from a search of recently published literature supplemented survey responses.

Summary of Findings

Below is a summary of findings in two topic areas:

- Survey of practice.
- Related research and resources.

Survey of Practice

Five of the 14 state DOTs receiving the survey responded: Minnesota, Montana, Pennsylvania, Utah and Washington. Survey findings are summarized below in the following topic areas:

- Cost estimating and risk management tools.
- PERT model use.
- Risk register use.

Cost Estimating and Risk Management Tools

All five agencies reported on at least one tool used for cost estimating or risk management:

- Minnesota DOT uses Real Estate Acquisition and Land Management System (REALMS), a Microsoft Excel-based tool developed in-house. The REALMS database contains all parcels within the agency's ROW, and uses historical data and trends to determine the probable percentage increase from the fair market value.
- Montana DOT uses two tools: AASHTOWare Project Estimation, which is used to determine cost estimates, and Project Risk Management Plan, a more complex risk management Excel spreadsheet for higher-risk projects.
- Pennsylvania DOT also uses two tools. PennDOT Risk Management Template, an Excel-based tool developed in-house, helps project teams focus on greatest risks and is used for projects of all levels of complexity. For complex projects with numerous risks and potentially detrimental effects, the agency uses the risk management tool developed in conjunction with the second Strategic Highway Research Program (SHRP2) Renewal Project 09, Managing Risk in Rapid Renewal Projects. Pennsylvania DOT was one of three lead adopter state agencies to use this tool.
- Utah DOT uses three tools to address differing levels of project complexity. The simplest tool is a qualitative risk worksheet that was developed in-house and is used to identify

and track risks, with project teams completing and updating the spreadsheet during regular meetings. The Excel-based Risk Model for Monte Carlo Analysis, which is used for projects with moderate levels of complexity, predicts risk costs and schedule effects. For very large projects, the agency employs consultants that use Monte Carlo-based simulation tools.

- Washington State DOT uses an in-house tool that runs a Monte Carlo analysis for all projects for which a cost risk analysis is desired or required. Consultants engaged by the agency for risk assessment of larger projects have used @Risk, a commercial risk assessment product available from Palisade Corporation.

Program Evaluation and Review Technique Model Use

Only two respondents reported using the PERT model in connection with cost estimating or risk management. Utah DOT's quantitative Risk Model for Monte Carlo Analysis estimates a range of potential outcomes for each ROW risk, capturing the high, low and most likely cost and schedule impacts of each risk. The calculated value is then incorporated into project cost and schedule impacts. Washington State DOT's in-house Monte Carlo simulation tool typically uses the PERT distribution for identified risks other than cost and schedule. The commercial tool used by Washington State DOT consultants offers a PERT distribution of three parameters: min, mode (most likely) and max.

Risk Register Use

Risk registers are used to identify, communicate, monitor and control risks. Minnesota DOT does not maintain a risk register; the Utah DOT respondent did not provide details of the risk register used in the agency's quantitative tool.

Montana DOT's respondent reported on two risk register items and the extent to which they might affect cost and schedule. One risk arose from wildlife migration, which would affect scheduling of projects. Respondents from Pennsylvania and Washington State DOTs provided substantial lists of ROW-related items included in their agency's risk registers. Both respondents indicated that determining cost and schedule impacts for each risk item is project-specific. Neither described in detail how their agency quantifies ROW-related risks in terms of cost and schedule.

Related Research and Resources

A limited literature search identified national publications such as the 2009 *NCHRP Report 625: Procedures Guide for Right-of-Way Cost Estimation and Cost Management*, guidance from state DOTs, and related resources addressing international approaches and new concepts such as PERT.

Gaps in Findings

The survey, which sought information from a relatively small group of potential respondents, received a limited response. Further attempts to engage with some or all of the nine agencies not responding to the survey could produce useful guidance. Portions of the survey also received a limited response, specifically related to how agencies quantify ROW-related items in risk registers in terms of cost and schedule. Follow-up inquiries with the two states reporting fairly extensive use of risk registers could garner more specific details.

Survey responses indicated that Utah and Washington State DOTs use PERT in connection with risk estimation. However, the respondents did not provide a significant level of detail about how PERT is used. Following up with these respondents may produce useful information.

Next Steps

Moving forward, Caltrans could consider:

- Contacting the Utah DOT and Washington State DOT respondents to learn more about the agencies' use of the PERT model in ROW-related risk management.
- Consulting with Pennsylvania DOT to learn more about the agency's experience working with the SHRP2 Excel-based risk management tool.
- Contacting selected respondents to learn more about the use of risk registers in connection with ROW-related risks.
 - Follow up with Pennsylvania and Washington State DOTs to inquire about agency management of the risk items identified in survey responses.
 - Follow up with Utah DOT to inquire about the specific risk items included in the agency's risk register and how they are managed.
- Examining in detail the tools and guidance for estimating ROW-related risks provided by survey respondents and addressed in other publications cited in this report.
- Working with the Caltrans Enterprise Risk Management Unit to conduct a risk assessment-focused analysis of the ROW tools the Division of Right of Way and Land Surveys wishes to consider.

Detailed Findings

Survey of Practice

The Caltrans Division of Project Management has developed an Excel-based risk tool that estimates support and capital risk-related costs and schedule impacts through all phases of project development. To identify the most effective inputs for this tool, the Caltrans Division of Right of Way and Land Surveys is seeking information from other state departments of transportation (DOTs) regarding their use of cost estimating and risk management tools, as well as tool inputs specifically related to right of way (ROW).

To inform Caltrans' use of appropriate inputs for its risk tool, CTC & Associates gathered information through a survey of state DOTs known to have experience with quantitative cost estimating or risk management tools. The survey questions are provided in [Appendix A](#). The full text of survey responses is provided in a supplement to this report.

Supplementing the survey responses are findings from a review of recently published literature; see the **Related Research and Resources** section beginning on page 17.

Summary of Survey Results

A survey was distributed to 14 state DOTs known to have experience with quantitative cost estimating or risk management tools:

- Florida.
- Georgia.
- Louisiana.
- Minnesota.
- Missouri.
- Montana.
- Nevada.
- New Jersey.
- New York.
- Ohio.
- Pennsylvania.
- Utah.
- Virginia.
- Washington.

The survey gathered information about the tools that agencies use for ROW cost estimating and/or risk management, and their use of program evaluation and review technique (PERT) to estimate project costs or schedules. (See the 2014 Caltrans *Workplan Standards Guide* cited on page 18 for a more detailed description of PERT.) The survey also sought to learn whether agencies use risk registers and their methods for quantifying risk in terms of cost and schedule.

Five state DOTs responded to the survey: Minnesota, Montana, Pennsylvania, Utah and Washington. Each state's quantitative cost estimating and risk management tools are described below. Publications relating to agency tools and practices supplement survey responses.

Minnesota Department of Transportation

The table below describes Minnesota DOT's Real Estate Acquisition and Land Management System (REALMS). Launched in 2005, REALMS was initially purchased as a database

framework from Virginia DOT and customized for Minnesota DOT's use. The table below that briefly describes this tool is followed by additional information about the agency's tool and practices.

Right of Way Cost Estimating/Risk Management Tool			
Tool	Tool Description	Features and Functions	Use of PERT
Real Estate Acquisition and Land Management System (REALMS)	<ul style="list-style-type: none"> • Database that contains all parcels within MnDOT's ROW. • Historical data and trends used to determine the probable percentage increase from the fair market value for properties to be acquired through direct purchase or the exercise of eminent domain. 	Historical data.	PERT is not used to generate project estimates.

Risk Register

The agency does not maintain a risk register.

Other Comments

Minnesota DOT develops an ROW estimate for the entire project through assessments, market rate, knowledge of a community's values, relocation possibilities and other similar factors, but it does not capture specific parcel values. These values have been subject to data practice requests and are brought forward in condemnation hearings.

Related Resources

MnDOT Parcels Acquired, Minnesota Department of Transportation, undated.

See [Attachment A](#).

This is the agency's annual report of ROW direct purchases and acquisitions for 2016.

Risk-Based Engineers Estimate, Jennifer S. Shane, Kelly C. Strong and Ghada M. Gad, Minnesota Department of Transportation, March 2015.

<http://www.dot.state.mn.us/research/TS/2015/201510.pdf>

From the abstract: The objective of this research is to:

- Conduct literature review of risk-based estimating.
- Conduct state-of-practice review of risk-based estimating used by DOTs and other construction organizations.
- Based on the state-of-practice and literature review conducted, give recommendations on how these practices can be incorporated into MnDOT's business practice.

The recommendations reached through this research are anticipated to help the MnDOT estimating team get a better understanding of risk-based estimating, and how it could be employed in the MnDOT estimation process.

“Right of Way Electronic Acquisition Land Management System and Geographic Information System Viewer,” Joseph D. Pignato, Minnesota Department of Transportation, 2014 AASHTO Subcommittee on Right of Way, Utilities and Outdoor Advertising Control Conference, 2014.

http://sp.rightofway.transportation.org/Documents/Meetings/2014%20Meeting%20Presentations/Database%20and%20Management%20Systems_REALMS%20and%20REALMS%20GIS%20-%20Presented%20by%20Joseph%20Pignato.pdf

This conference presentation provides a brief overview of REALMS and the recently added GIS capabilities.

Montana Department of Transportation

The Montana DOT respondent reported on two tools: AASHTOWare Project Estimation and Project Risk Management Plan, an Excel-based spreadsheet. The table below that briefly describes each tool is followed by additional information about the agency’s tools and practices.

Right of Way Cost Estimating/Risk Management Tools			
Tool	Tool Description	Features and Functions	Use of PERT
Project Estimation (AASHTOWare)	<ul style="list-style-type: none"> Used throughout the project’s design life to determine the cost estimate for project construction. Uses statistical analysis to determine bid item pricing based on project location, quantity and, potentially, work type. 	<ul style="list-style-type: none"> Contingency ranges. Statistical analysis to determine bid item pricing. (See Related Resources below for information about this commercially available tool.)	PERT is not used to generate project estimates.
Project Risk Management Plan	<ul style="list-style-type: none"> Used in a limited capacity on projects determined to be high risk. Design team reviews both the project and the identified risks and mitigation throughout the design process. Not used as frequently as it could be. 	<ul style="list-style-type: none"> Excel-based tool. Risk register. Probability ratings. Contingency ranges. 	PERT is not used to generate project estimates.

Risk Register

Montana DOT maintains a list of ROW-related risks. The respondent reported on the following risks and the agency’s response to quantify or manage them:

Risk: Condemnation process takes longer than anticipated.

Response: Try to account for this in the schedule. It does not appreciably affect cost.

Risk: Environmental issues other than hazardous waste may impact ROW acquisition.

Response: Review for schedule impacts due to timing restrictions related to migratory birds, fish and other migrating animals.

Other Comments

The agency's external consultants are still using an older Excel spreadsheet estimating tool and will receive upgrades to the new system as soon as the necessary server hardware is installed.

Related Resources

AASHTOWare Project Estimation, American Association of State Highway and Transportation Officials, undated.

https://www.aashtoware.org/wp-content/uploads/2018/10/02_AWP-Estimation.pdf

From the document: The AASHTOWare Project Estimation module is a web-based cradle-to-grave estimation application designed to deliver accurate, reliable estimates for your construction program. ... AASHTOWare Project Estimation includes the assessment and assignment of the risk contingency, life cycle analysis tools, expansion of existing import/export capabilities, the inclusion of non-bid costs, non-construction costs and markups, and the ability to utilize snapshots in the creation of an audit trail for the agency's estimates.

Risk Management: Tools and Resources, Design Consulting, Montana Department of Transportation, undated.

<https://www.mdt.mt.gov/business/consulting/risk-mgmt.shtml>

This web site provides resources associated with the agency's risk management tools and practices, including the Excel-based Project Risk Management Plan (see below).

Related Resource:

Project Risk Management Plan Workbook (RMP), Montana Department of Transportation, undated.

https://www.mdt.mt.gov/other/webdata/external/cadd/report_templates_guidance/RMP_MDT.XLSM

This is the template for the agency's Excel-based Project Risk Management Plan tool. *From the foreword:*

This workbook contains many tools for performing risk management. Each tool is contained in a separate worksheet. The primary tools are the Project Level of Risk table and the RMP. The Project Level of Risk table is to be used for determining the potential for risk. The RMP is the risk register and management document for capturing potential risk and associated mitigation. The Risk Checklist is the risk register and tracking document for low risk projects.

Cost Estimating: Tools and Resources, Design Consulting, Montana Department of Transportation, undated.

<https://www.mdt.mt.gov/business/contracting/cost.shtml>

This web site provides resources related to the agency’s cost estimating tools and practices, including the following document that briefly describes the use of AASHTOWare Project Estimation:

Cost Estimation Procedure for Highway Design Projects, Montana Department of Transportation, November 2016.

https://www.mdt.mt.gov/other/webdata/external/cadd/report_templates_guidance/costest_procedure.pdf

This procedure is used to “maintain consistency within the Engineering Division regarding cost estimates; to get cost estimates that more accurately reflect the final construction costs.”

Pennsylvania Department of Transportation

The Pennsylvania DOT respondent described two Excel-based tools: PennDOT Risk Management Template and a risk management tool developed through the second Strategic Highway Research Program (SHRP2). The table below that briefly describes each tool is followed by additional information about the agency’s tools and practices.

Right of Way Cost Estimating/Risk Management Tools			
Tool	Tool Description	Features and Functions	Use of PERT
PennDOT Risk Management Template	<ul style="list-style-type: none"> • Uses risk registers and probability ratings. • Applies to a wide range of project complexity, including noncomplex, moderately complex and some major projects. • Helps users focus on the highest severity risks and ensures that the risk owner will follow up appropriately. 	<ul style="list-style-type: none"> • Excel-based. • Risk register. • Probability ratings. 	PERT is not used to generate project estimates.
Risk Management Tool (SHRP2 Renewal Project R09)	<ul style="list-style-type: none"> • Offers project structuring and cost–benefit analysis for a selection of risk responses. • Recommended for complex projects that “contain a substantial number of risks that can have significant detrimental impact on a budget and schedule.” <p>(The agency was one of three lead adopter state transportation agencies.)</p>	<ul style="list-style-type: none"> • Excel-based. • Probabilistic analysis. • Risk register. • Contingency ranges. 	PERT is not used to generate project estimates.

Risk Register

The respondent offered a substantial list of risk items included in the agency’s risk register. (See [Attachment B](#) for additional information about the agency’s use of a risk register.) For each risk

item, the respondent identified the same method of risk quantification, noting that “cost and schedule impacts are project-specific. Through a comprehensive team discussion session, cost and schedule impacts, as well as the impacts of mitigation strategies, are identified by leveraging the expertise of team members on all issues regarding a particular risk.”

See below for the list of risks included in Pennsylvania DOT’s risk register:

- Access to adjacent properties needed but not planned for.
- Condemnation process takes longer than anticipated.
- Discovery of hazardous waste.
- Inadequate pool of qualified appraisers.
- Insufficient ROW available for all operations.
- Landowners unwilling to sell.
- Need for “permits to enter” not considered in project development.
- Parcel acquisitions controlled by state or federal partners take longer than anticipated.
- Resolving objections to ROW appraisal takes more time and/or money.
- ROW clearance not received in time for advertising.
- Unanticipated escalation in ROW values.
- Unanticipated need for public hearing related to ROW acquisition.
- Unforeseen railroad engagement needed.

Related Resources

Appendix AG: Risk Management for Project Development, Pennsylvania Department of Transportation, November 2015.

See [Attachment B](#).

An introductory note in this 44-page appendix indicates that portions of this document were developed using the June 2012 Caltrans publication, *Project Risk Management Handbook: A Scalable Approach*, and the SHRP2 publication, *Guide for the Process of Managing Risk on Rapid Renewal Projects*. The document defines risk management; discusses risk management levels, responsibilities and project integration; outlines the risk management process and how to use risk management tools; and provides risk response examples.

PennDOT Risk Management Template, Pennsylvania Department of Transportation, 2017. Provided to Caltrans separately.

This Excel workbook provides guidance for three levels of analysis: risk identification, probability and impact ratings for Level 2 projects, and entering quantifications into the risk register for Level 3 projects.

Guide for the Process of Managing Risk on Rapid Renewal Projects, Renewal Project R09, Transportation Research Board, 2014.

Publication available at <http://www.trb.org/Main/Blurbs/168369.aspx>

From the publication description: TRB’s second Strategic Highway Research Program (SHRP 2) S2-R09-RW-2: Guide for the Process of Managing Risk on Rapid Renewal Projects describes a

formal and structured risk management approach specifically for rapid renewal design and construction projects that is designed to help adequately and efficiently anticipate, evaluate and address unexpected problems or “risks” before they occur.

In addition to the report, the project developed three electronic tools to assist with successfully implementing the guide:

- The [rapid renewal risk management planning template](#) will assist users with working through the overall risk management process.
- The [hypothetical project using risk management planning template](#) employs sample data to help provide an example to users about how to use the rapid renewal risk management template.
- The [user’s guide for risk management planning template](#) will provide further instructions to users who use the rapid renewal risk management template.

Renewal Project R09 also produced a [PowerPoint presentation](#) on risk management planning.

Related Resources:

Managing and Reducing Risk in Accelerated Highway Construction Projects: Managing Risk in Rapid Renewal Projects (R09), SHRP2: Solutions for the Road, Transportation Research Board, undated.

<https://www.fhwa.dot.gov/GoSHRP2/Solutions/Renewal/R09>

From the web site:

Unmanaged risks can lead to project delays and increased costs—on projects of any size and scope. R09, also known as Managing Risk in Rapid Renewal Projects, can improve project outcomes by allowing teams to anticipate, assess, and plan up front, helping agencies mitigate risks (threats) and seize opportunities.

R09 is designed to help transportation agencies apply risk management in-house. A spreadsheet-based template guides project teams through the risk management process, which includes confirming project scope, strategy, and conditions; identifying, assessing, and prioritizing risks; and ultimately developing a strategy to mitigate and proactively manage risks. An accompanying Guidebook provides tools to assist with each step.

Managing Risk in Rapid Renewal Projects (R09): A Seven-Step Risk Management Process, Renewal Project R09, Transportation Research Board, undated,

https://www.fhwa.dot.gov/majorprojects/project_management/r09/evaluation.pdf

This two-page brochure describes SHRP2 Renewal Project 09. Project benefits include reducing project costs and shortening project timelines, helping agencies adopt risk management in their state agencies, and allowing states to identify a more comprehensive and project-specific set of risks.

Utah Department of Transportation

Utah DOT uses three tools or approaches to estimate project costs and risks:

- Qualitative risk worksheet for smaller projects.
- Quantitative Risk Model for Monte Carlo Analysis for projects with a “medium” level of risk.
- Consultant-based risk program that uses Monte Carlo–based tools for very large projects.

The table below that briefly describes each tool is followed by additional information about the agency’s tools and practices.

Right of Way Cost Estimating/Risk Management Tools			
Tool	Tool Description	Features and Functions	Use of PERT
Qualitative Risk Worksheet	<ul style="list-style-type: none"> • Is the simplest of the three tools. • Used to identify and track risks. • Does not calculate risk costs or schedule impacts. • Used by project teams to identify and track risks during regular meetings. 	<ul style="list-style-type: none"> • Developed in-house. • Excel-based. • Risk register. • Probability ratings. • Owners assigned to risks for future follow-up. 	PERT is not used to generate project estimates.
Risk Model for Monte Carlo Analysis	<ul style="list-style-type: none"> • Used for projects with a “medium” level of risk. • Similar to the qualitative tool but uses Monte Carlo simulation to predict risk costs and schedule impacts. 	<ul style="list-style-type: none"> • Monte Carlo quantitative analytical tool. • Excel-based. • Probabilistic analysis. • Risk register. • Probability ratings. • Contingency ranges. 	A range of potential outcomes is estimated for each ROW risk, capturing the high, low and most likely cost and schedule impact of each risk. The calculated value is incorporated into project cost and schedule impacts.
Cost Estimate Validation Process-Type Tools	The agency hires consultants to develop and manage risk programs for very large projects. Consultants employ a variety of risk tools, all of them Monte Carlo–based.	<ul style="list-style-type: none"> • Monte Carlo quantitative analytical tool. • Excel-based. • Probabilistic analysis. • Risk register. • Contingency ranges. 	See the above description for the use of PERT.

Risk Register

While all three tools used by Utah DOT employ a risk register, the respondent did not indicate the specific ROW-related risk items included in those registers or how each risk is quantified in terms of cost and schedule.

Related Resources

UDOT Qualitative Risk Worksheet, Utah Department of Transportation, July 2016.

<https://www.udot.utah.gov/main/uconowner.gf?n=12393505902742100>

This Excel workbook is the agency's simplest risk management tool.

Related Resources:

Instructions on Using Qualitative Risk Worksheet, Utah Department of Transportation, November 2014.

<https://www.udot.utah.gov/main/uconowner.gf?n=12393414167716126>

This document describes the agency's decision tree and the Excel-based qualitative risk workbook.

Qualitative Risk Worksheet, Utah Department of Transportation, undated.

<http://connect.udot.utah.gov/p2j3k7ob6c2/>

This video introduces version 2 of the qualitative risk worksheet.

UDOT Risk Model for Monte Carlo Analysis, Utah Department of Transportation, November 2014.

<https://www.udot.utah.gov/main/uconowner.gf?n=18477703684179398>

This is the interactive Excel workbook for the agency's "medium-level" risk tool.

"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 members use to select the most appropriate tool for a risk assessment.

Washington State Department of Transportation

The Washington State DOT respondent reported on two tools: an in-house tool that uses Monte Carlo simulation to conduct a quantitative analysis, and Palisade Corporation’s @Risk, an add-in to Excel, which is often used by consultants. The table below that briefly describes each tool is followed by additional information about the agency’s tools and practices.

Right of Way Cost Estimating/Risk Management Tools			
Tool	Tool Description	Features and Functions	Use of PERT
Project Risk Analysis Model	Used for all projects for which a cost risk analysis is desired or required.	<ul style="list-style-type: none"> • Excel-based. • Monte Carlo analysis. • Probabilistic analysis. • Deterministic analysis. • Risk register. • Probability ratings. • Contingency ranges. (See the User’s Guide: Project Risk Analysis Model cited in Related Resources below for further details of the tool’s features and functions.)	Uses PERT to estimate unspecified factors other than cost and schedule.
@Risk (Palisade Corporation)	Used by consultants employed by the agency.	(See Related Resources below for more information about this commercially available tool.)	RiskPert distribution uses three parameters: min, mode (most likely) and max. (See Related Resources for more information about RiskPert.)

Risk Register

The respondent provided the following risk items that are included in the agency’s risk register, noting that risk registers are project-specific and vary accordingly:

- Access to adjacent properties needed but not planned for.
- Condemnation process takes longer than anticipated.
- Discovery of hazardous waste.
- Environmental issues other than hazardous waste that may impact ROW acquisition.
- Expired temporary construction easements.
- Insufficient utility company participation or engagement.
- Need for “permits to enter” not considered in project development.
- Parcel acquisitions controlled by state or federal partners take longer than anticipated.

- Potential need to switch identified partial parcel acquisitions to full parcel acquisitions due to uneconomic remnants.
- ROW clearance not received in time for advertising.
- Seasonal impacts associated with utility relocation.
- Subsurface easements and/or air easements.
- Unanticipated escalation in ROW values.
- Unanticipated need for public hearing related to ROW acquisition.
- Unforeseen railroad engagement needed.
- Utility relocation requires more time than planned.

For each risk item, the respondent identified the same method of risk quantification, noting that project teams determine the probability and range for cost and schedule.

Related Resources

Strategic Analysis and Estimating Office (SAEO) Home, Washington State Department of Transportation, 2019.

<http://www.wsdot.wa.gov/Design/SAEO/>

As this web site indicates, “SAEO is part of the WSDOT Project Development Division, providing technical support in the disciplines of estimating, risk analysis, value engineering, practical design, project development and training.” The site offers links to a wide range of resources. Some of the publications most relevant to ROW-related risk analysis are cited below.

Project Risk Management Guide, Engineering and Regional Operations, Washington State Department of Transportation, February 2018,

<http://www.wsdot.wa.gov/publications/fulltext/cevp/ProjectRiskManagement.pdf>

Part I of this guide includes descriptions of the agency’s risk management planning and identification and the tools used to monitor risk. Included is a discussion of the agency’s use of a risk breakdown structure, which is used for organizing risks, and for monitoring, tracking and reporting on risk status.

Project Risk Analysis Model, Washington State Department of Transportation, undated.

<http://www.wsdot.wa.gov/publications/fulltext/CEVP/PRAM.xlsm>

This Excel workbook contains the agency’s Excel-based quantitative tool that uses Monte Carlo simulation to generate cost and schedule probability distributions.

Related Resource:

User’s Guide: Project Risk Analysis Model, Washington State Department of Transportation, March 2018.

http://www.wsdot.wa.gov/publications/fulltext/CEVP/PRAM_Users_Guide.pdf

From the overview: The Project Risk Analysis Model (PRAM) uses Monte Carlo simulation to generate cost and schedule probability distributions from user input cost, schedule, risk and uncertainty information. It produces quantitative risk analysis outputs that provide actionable information to project managers and teams.

The model runs thousands of simulations or “project realizations” that virtually execute the project under the influence of all input uncertainties and risks. For each realization some

risks occur, some do not; some impacts are high and others are low. The output provides an estimated range of project cost and schedule outcomes. Few realizations reach the extreme limits of the distribution, most aggregate toward the middle.

Up to 24 individual risks may be entered into the model. The outputs present statistical summaries, graphically as a distribution histogram, a cumulative distribution function S-curve, and as a percentile table. The model reports cost distribution forecasts for Preliminary Engineering (PE), Right of Way (RW), and Construction (CN) as well as total project cost. Results are provided in Current Year (CY) dollars and as inflated to Year of Expenditure (YOE) dollars. There are two schedule distribution forecasts, contract advertisement date and end of construction date. There are also tornado diagrams, sorting risks by expected value (EV), by cost and schedule impact.

The model accommodates two analyses. The first is for analyzing project estimate exposure to risks as initially identified and assessed, and the second is for analyzing the response to those risks. Comparing the pre-mitigated and post mitigated results offers users a quantified measure of the value added by proactive project risk management. The Base Estimate and Risk input forms serve both analyses.

@Risk for Risk Analysis, Palisade Corporation, undated.

<https://www.palisade.com/risk/default.asp>

From the web site:

@RISK (pronounced “at risk) is an add-in to Microsoft Excel that lets you analyze risk using Monte Carlo simulation. @RISK shows you virtually all possible outcomes for any situation and tells you how likely they are to occur.

A description of @Risk’s key features is available at <https://www.palisade.com/risk/key-features.asp>; more information about Monte Carlo simulation is available at https://www.palisade.com/risk/monte_carlo_simulation.asp.

Related Resource:

Example Models: RiskPert Function, @Risk Distributions, Palisade Corporation, 2019.

<https://www.palisade.com/downloads/examples/General/Distributions/RiskPertFunction.xlsx>

This Excel workbook includes a description of the RiskPert function and a sample model illustrating its use.

Related Research and Resources

Below is a sampling of recent publicly available resources that are organized into three topic areas:

- National resources.
- State guidance.
- Related resources.

National Resources

Managing Risk Across the Enterprise: A Guide for State Departments of Transportation, Gordon Proctor, Shobna Varma and Jeff Roorda, NCHRP Project No. 08-93, June 2016.

http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-93_FullGuide.pdf

From the abstract: This guide explains how state transportation agencies can establish and benefit from an enterprise risk management program. It defines risk management and illustrates how it complements strategic planning and performance management. The guide explains how the managing of risk provides agencies with a new set of skills to increase the likelihood that they will achieve their strategic objectives. The guide focuses upon enterprise risk management, which is defined as the formal and systematic effort to control uncertainty and variability to an organization's strategic objectives by managing risks at all levels of the organization. The guide also explains how to manage risks at four levels, the enterprise, program, project, and activity levels. The guide includes extensive summaries of how risk management is being applied nationally and internationally to typical transportation program areas.

NCHRP Report 658: Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs, Keith Molenaar, Stuart Anderson and Cliff Schexnayder, 2010.

Project description at <http://www.trb.org/Publications/Blurbs/163722.aspx>

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.

NCHRP Report 625: Procedures Guide for Right-of-Way Cost Estimation and Cost Management, Stuart Anderson, Keith Molenaar and Cliff Schexnayder, 2009.

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_625.pdf

From the foreword: This procedures guide presents practical and effective approaches for developing right-of-way (ROW) cost estimates and for then tracking and managing ROW cost during all phases of project development, including planning, programming, and preliminary and final design. It is a resource for managers, practitioners and decision makers interested in developing and managing realistic and accurate estimates of ROW cost from the earliest ROW cost estimate made during planning through to the management of ROW acquisition cost during final design.

Major Project Program Cost Estimating Guidance, Federal Highway Administration, January 2007.

https://www.fhwa.dot.gov/majorprojects/cost_estimating/major_project_cost_guidance.pdf

This brief document has very general guidance about creating cost estimates for major projects. *From the introduction:*

This guidance is for the preparation of a total program cost estimate for a major project. For the purpose of this guidance, a major project is defined as a project that receives any amount of Federal financial assistance and has an estimated total program cost greater than \$500 million (expressed in year-of-expenditure dollars), or other projects identified as a major project by the FHWA. The total program cost estimate includes construction, engineering, acquisition of right-of-way, and related costs, which will be identified by this guidance. Although this guidance is for major projects, it may also be applied to other projects.

State Guidance

California

Division of Transportation Planning Interim Guidelines for State Highway Operation and Protection Program Project Initiation Report, California Department of Transportation, January 2018.

http://www.dot.ca.gov/hq/tpp/offices/opsc/shopp-guidance/janrevise/01_22_18PIR-InterimGuidance.docx

Appendix A, Cost Estimating, begins on page 24 of the document and includes a brief discussion of PERT.

Workplan Standards Guide; Release 11.0 for Capital Outlay Projects, California Department of Transportation, 2014.

http://www.dot.ca.gov/hq/projmgmt/documents/wsg/WSG_v11-0_2014.pdf

Pages 9 and 10 of the guide (pages 13 and 14 of the PDF) provide the following overview of PERT:

Principles of PERT

The PERT principles were developed in 1958 as a tool for estimating the cost and schedule of nuclear submarines. It is based on three principles:

- An expert's estimate of the cost of a task that takes one day to complete is likely to be more accurate than their estimate of a task that takes a year to complete. The longer and larger the task, the more difficult it is to visualize the effort required.
- 95 percent of the area under a "normal" distribution curve lies within two standard deviations of the mean.
- Given several independent variables (a, b, c, ... n), each with its own standard deviation, ($s_a, s_b, s_c, \dots, s_n$), the standard deviation of $(a+b+c+ \dots+n)$, is the square root of the sum of the squares of the standard deviations $s_{(a+b+c+ \dots+n)} = (s_a^2+s_b^2+s_c^2+ \dots S_n^2)^{0.5}$.

PERT Procedure

PERT may be used for estimating project costs or schedules. The PERT process is as follows.

- Establish a WBS [work breakdown structure] for the project.
- For each lowest-level work package in the WBS, assemble a team of people who have the greatest experience in producing that type of package.
- Have each team member develop three estimates for the particular package:
 - An optimistic estimate (o): The lowest credible cost or schedule assuming that everything goes right.
 - A most-likely estimate (m): The team member's best guess of the actual outcome.
 - A pessimistic estimate (p): The highest credible cost or schedule, assuming that virtually everything goes wrong, but that the team continues working on the project.²
- The average estimated cost or schedule of the work package is $(o+4m+p)/6$.
- The standard deviation for the work package is $swp = (p-o)/4$.³
- The standard deviation of the project is $s_{\text{project}} = (s_{\text{wp1}}^2 + s_{\text{wp2}}^2 + s_{\text{wp3}}^2 + \dots + s_{\text{wpn}}^2)^{0.5}$. If one is estimating the schedule, wp1 through wpn are the work packages on the critical path. For costs, wp1 through wpn are all the work packages at the lowest level of the WBS.

- 2 If the team stops working on the project, the project will never finish and the highest credible schedule is infinite. For estimating purposes, one must assume that the team continues to work on the project.
- 3 Derived from the principle that 95% of events occur within two standard deviations of the mean.

Georgia

Streamlining Project Delivery Through Risk Analysis, Georgia Department of Transportation, 2015.

http://g92018.eos-intl.net/eLibSQL14_G92018_Documents/13-05.pdf

Researchers examined the practices of other state DOTs in connection with the development of a tool that will identify and qualitatively assess project risks. *From the abstract:*

A comprehensive list of potential risks for transportation projects was developed based on reviewing the academic/professional literature, current state of practice in risk management among leading state DOTs, and current state of practice of GDOT. During several meetings with higher level risk management experts at GDOT, the most important risks were [identified] and a short list of major potential risks was developed for each office at GDOT. Finally, a software tool specifically designed for identification and qualitative assessment of highway project risks during the pre-construction phase of the project was developed based on the shortlisted risk factors. The software program is equipped with the modification capability of adding new risk items and/or removing some of the predetermined risk factors from the assessment.

Montana

Top-Down Construction Cost Estimating Model/Guide Using a Neural Network, Douglas D. Gransberg, H. David Jeong, Ilker Karaca and Brendon Gardner, Montana Department of Transportation, July 2017.

https://www.mdt.mt.gov/other/webdata/external/research/DOCS/RESEARCH_PROJ/top-down_cost_estimating/Final_Report.PDF

From the abstract: This report contains the information and background on top-down cost estimating using artificial neural networks (ANN) to enhance the accuracy of MDT early estimates of construction costs. Upon conducting an extensive review of MDT's budgeting and cost estimating efforts, and following a survey of agency experts on the identification of the most salient project attributes with the dual-objectives of low effort and high accuracy, a rational method for top-down variable selection is proposed.

Selected variables were further tested in their explanatory power of construction costs through the application of two cost estimating methodologies—multiple regression and artificial neural network methodologies. Both methods are shown to provide sizeable improvements over the agency's current levels of prediction accuracy for its construction costs. Potential accuracy gains are also demonstrated to depend on project work types. The comparison of mean absolute percentage errors across different estimating methods confirms that the potential benefits from the proposed methodologies are expected to rise as the project level complexity and uncertainty increase. New construction and bridge replacement projects, for instance, are expected to gain the most in estimating accuracy since these two groups seem to exhibit considerably higher levels of deviation from the MDT's preliminary cost estimates.

To facilitate MDT's implementation of the suggested methodology described in this report, a cost estimation methodology was also presented in an Excel spreadsheet format. This achieves two goals. First, it provides an accessible tool to make top-down cost predictions for agency planners during the budgeting stage based on MDT's historical project data. Second, it furnishes a process through which the proposed model can be improved as new project information becomes available. Ultimately, the insights gained from this study are expected to contribute to a better formulation of the agency's early cost estimation and budgeting efforts.

Nevada

Risk Management and Risk-Based Cost Estimation Guidelines, Nevada Department of Transportation, August 2012.

<https://www.nevadadot.com/home/showdocument?id=4518>

From the foreword: These guidelines address the first step in NDOT project management's vision of achieving statewide uniformity and consistency of project cost estimates and department-wide priority on estimating, managing, and controlling costs. Risk-based cost estimation and risk management involves the use of resources, including personnel that have the necessary knowledge, skills, and abilities to accurately and consistently predict costs.

Virginia

Virginia Public-Private Partnerships: P3 Risk Management Guidelines, Commonwealth of Virginia, March 2015.

http://www.p3virginia.org/wp-content/uploads/2015/03/Risk-Management-Guidelines_3.20.2015.pdf

From the executive summary: These P3 Risk Management Guidelines (Guidelines), which were developed by the Virginia Office of Public-Private Partnerships (VAP3), describe a Risk Management Framework that should be utilized on Public-Private Partnership (P3) projects throughout their entire lifecycle from the initial screening to handback. These Guidelines are part of a suite of documents, including the PPTA Implementation Manual and Guidelines, which assist the VAP3 and Commonwealth Agencies with successful development and implementation of P3 projects. The purpose of the P3 Risk Management Guidelines is to achieve the following goals and objectives:

- Provide practical guidance to the project team executing the Risk Management Framework during the whole project lifecycle of P3 projects.
- Increase consistency and effectiveness of the Risk Management Framework by describing specific Risk Management activities throughout a P3 project's lifecycle.
- Provide a consistent set of Risk Management terminology.
- Promote effective communication and consultation regarding Risk Management with internal and external Stakeholders.
- Establish a confident and rigorous basis for decision-making and planning in regard to risk.
- Strengthen current Risk Management tools and techniques by incorporating national and international best practices.
- Increase Risk Management accountability of the Agency undertaking a P3 project through the certification of certain risk documents.
- Emphasize the performance goals, measures, review and modification process to ensure continuous improvement of the Risk Management Framework.
- Improve transparency by making risk information and reports available on the VAP3 website, project website and/or other appropriate means.

Related Resources

Transportation Risk Management: International Practices for Program Development and Project Delivery, International Technology Scanning Program, Federal Highway Administration, August 2012.

https://international.fhwa.dot.gov/scan/12029/12029_report.pdf

From page 2 of the report (page 14 of the PDF): From May 26 to June 12, 2011, a U.S. panel traveled to Australia and Europe to learn from their significant experience by conducting a scan of risk management practices for program development and project delivery. The purpose of the scan was to review and document international policies, practices, and strategies for potential application in the [United] States. The team conducted meetings with government agencies, academic researchers, and private sector organizations that actively participate in risk

management efforts. The scan team also visited project sites and personnel who were applying these practices.

“New Approach to Developing Conceptual Cost Estimates for Highway Projects,” Mounir El Asmar, Awad S. Hanna and Gary C. Whited, *Journal of Construction Engineering and Management*, Vol. 137, No. 11, pages 942-949, November 2011.

Citation at <http://trid.trb.org/view/1124747>

From the abstract: Developing a reliable project cost estimate is a challenge for any state highway agency (SHA), especially at the conceptual stage. A conceptual estimate is defined in this paper as the estimate prepared at the point at which only 30% of the design is complete. This paper describes a statistical approach to producing a reliable conceptual cost estimate when few project design details have been finalized and many assumptions still form the basis of the estimate. This approach used an analysis similar to the program evaluation and review technique (PERT), which is more commonly used in project scheduling, to assign certainty factors to cost estimates. The approach uses a combination of historical bid data for major roadway items whose quantities can be estimated early in the development process and historical percentages for other major components of the project, called allowance and contingency factors. The paper focuses on (1) the methodology developed to analyze the historical bid data; (2) the analysis of 14 highway corridors with 77 projects whose as-bid construction costs were more than \$830 million; and (3) a cross-validation of the approach used to validate the accuracy of the predictive model. By using a PERT-type technique, construction costs were accurately predicted at the conceptual stage within $\pm 20\%$. However, approximately 85% of the corridor costs were accurately predicted within $\pm 15\%$ of the actual cost. The proposed methodology provides a structured and consistent estimating approach that can be used by any SHA that needs to develop total project delivery estimates at the conceptual design stage.

Contacts

CTC contacted the individuals below to gather information for this investigation.

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Appendix A: Survey Questions

The following survey was distributed to selected state departments of transportation known to have experience with quantitative cost estimating or risk management tools.

Describing Your Agency's Cost Estimating and Risk Management Tools

Your agency may use more than one cost estimating or risk management tool. The questions below offer **three opportunities** to describe the **primary tools** your agency uses in connection with cost estimating and risk management. Please complete as many sections as are needed to describe the tools your agency uses.

(The following set of three questions appears three times, listed as "Tool One," "Tool Two" and "Tool Three," to allow respondents to describe up to three of their agencies' tools.)

1. Please provide the names of the cost estimating or risk management tool your agency uses and the vendor supplying the tool, if applicable.
2. Please briefly describe how this tool is used.
3. Please identify the **features** and **functions** of your agency's tool by selecting all that apply.
 - Monte Carlo quantitative analytical tool.
 - Excel-based tool.
 - Probabilistic analysis.
 - Deterministic analysis.
 - Risk register.
 - Probability ratings.
 - Contingency ratings.
 - Program evaluation and review technique (PERT) model (three values used to arrive at a final estimate).
 - Other (please describe).

Right of Way Inputs

Note: Question 1 addresses the use of program evaluation and review technique (PERT), which is used as an estimating technique. PERT uses a weighted average of three values to come up with a final estimate:

- The most pessimistic (P) case when everything goes wrong.
- The most optimistic (O) case when everything goes right.
- The most likely (M) case.

-
1. If your agency is using a PERT model to prepare project estimates, please describe how ROW-related risks are treated within the PERT model.
 - Our agency doesn't use the PERT model to generate project estimates.

- Our agency uses the PERT model to estimate factors **other than** cost and schedule.
 - Our agency uses the PERT model to estimate costs and/or schedules. (Please briefly describe below how the PERT model is applied to ROW-related costs and schedules.)
2. Does your agency maintain a list (sometimes called a risk register) of ROW-related risks?
- No (click on the “Next” button).
 - Yes (respond to Questions 3 and 4 below).
3. What does your agency’s risk register for ROW risks include? Select all that apply.
- Access to adjacent properties needed but not planned for.
 - Condemnation process takes longer than anticipated.
 - Discovery of hazardous waste.
 - Environmental issues other than hazardous waste that may impact ROW acquisition.
 - Expired temporary construction easements.
 - Inadequate pool of ROW experts to conduct appraisals and other ROW-related activities.
 - Insufficient ROW available.
 - Insufficient utility company participation or engagement.
 - Need for “permits to enter” not considered in project development.
 - Parcel acquisitions controlled by state or federal partners take longer than anticipated.
 - ROW clearance not received in time for advertising.
 - Seasonal impacts associated with utility relocation.
 - Unanticipated escalation in ROW values.
 - Unanticipated need for public hearing related to ROW acquisition.
 - Unforeseen railroad engagement needed.
 - Utility relocation requires more time than planned.
 - Other (please describe).
4. For each risk you checked in Question 3, please describe below how the risk is quantified in terms of cost and schedule.
- Access to adjacent properties needed but not planned for.
 - Condemnation process takes longer than anticipated.
 - Discovery of hazardous waste.
 - Environmental issues other than hazardous waste that may impact ROW acquisition.
 - Expired temporary construction easements.

- Inadequate pool of ROW experts to conduct appraisals and other ROW-related activities.
- Insufficient ROW available.
- Insufficient utility company participation or engagement.
- Need for “permits to enter” not considered in project development.
- Parcel acquisitions controlled by state or federal partners take longer than anticipated.
- ROW clearance not received in time for advertising.
- Seasonal impacts associated with utility relocation.
- Unanticipated escalation in ROW values.
- Unanticipated need for public hearing related to ROW acquisition.
- Unforeseen railroad engagement needed.
- Utility relocation requires more time than planned.
- Other (please describe).

Wrap-Up

1. Do you have documents related to your agency’s cost estimating and risk management tool(s) and the associated ROW-related inputs that you can share? Provide links below to these documents or email them to chris.kline@ctcandassociates.com.
2. Please use this space to provide any comments or additional information about your previous responses.