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Managing Risk across the Enterprise:

FINAL

A Guide for State Departments of Transportation

Prepared for
The National Cooperative Highway Research Program
Of
The National Academies

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 08-93

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TRANSPORTATION RESEARCH BOARD

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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.

Introduction—About this Guide

This guide for state departments of transportation (DOTs) provides a comprehensive framework to identify and manage risk. It will help state DOTs plan, staff, implement, and evaluate consistent and effective enterprise risk management efforts. It demonstrates the benefit and strategic value of enterprise risk management to executive and senior staff while building on the findings of previous research and international scan findings. The guide defines risk management, explains its components, and illustrates how it can improve performance, credibility, and transparency.

For U.S. transportation agencies, risk management generally has been confined to managing risks to construction project cost, scope, and schedule. The expansion of interest in enterprise risk management reflects a growing recognition that risk management can play an important, broader role. It can help organizations manage risks to all objectives, not just those related to project schedules and scopes.

Risk management is the natural complement to performance and asset management. Performance management leads agencies to set goals and direct resources to achieve them. However, all goals face uncertainties and risks. Risk management helps identify, measure, manage, and mitigate those risks. It provides a realistic assessment of the uncertainties or impediments surrounding an organization's objectives and a systems approach to addressing them. As agencies move into the performance era inaugurated by the Moving Ahead Progress in the 21st Century Act (MAP-21), they will find enterprise risk management to be a complementary framework to help them achieve their performance objectives.

Risk management also helps make difficult investment tradeoffs. By casting decisions in terms of risk, agencies can clarify and explain investment priorities.

Even if not spurred by MAP-21, U.S. transportation agencies are well served by enterprise risk management. Applying risk management to transportation agencies transfers a sound management practice from the corporate world to the public sector. In the corporate world, risk management is viewed as a basic competency. It recognizes that in a complex environment, achievement of organizational goals depends on managing many internal and external risks. Failure to measure, manage, and mitigate these risks increases the likelihood of failure. If risks and uncertainties are inevitable, failing to consider them is irresponsible.

This guide helps an agency create an enterprise risk management program. It defines enterprise risk management as a comprehensive approach to addressing risks at all levels of the organization. Because an agency's strategic objectives depend on achieving goals and targets at every level, enterprise risk management drills down to the program, project, and activity levels. It illustrates the integration of risk management into an agency's key programs by explaining how it can be applied not only to strategic objectives, but also to the following:

- Transportation asset management
- Highway safety

- External threats, such as climate change
- Financial forecasting
- Information or decision risks
- Program and project risks related to costs, scopes, and schedule
- Traditional business operation risks, such as theft and workforce injuries.

This guide expands on earlier research. The report on National Cooperative Highway Research Program (NCHRP) Project 20-24 (74), *Executive Strategies for Risk Management by State Departments of Transportation*, analyzed information from 43 state DOTs and identified executive-level strategies for implementing enterprise-wide risk management. A 2011 international scan of transportation agency risk management practices found that leading transportation agencies in Australia, England, Germany, the Netherlands, and Scotland have mature risk management policies and procedures. It is entitled *Transportation Risk Management: International Practices for Program Development and Project Delivery.* The 2012 NCHRP Web-Only Document 183, *Guide for Managing NEPA-Related and Other Risks in Project Delivery*, addressed risks related to National Environmental Policy Act (NEPA) decision making.

How to Use this Guide

A well-known adage says some people just want to tell time and others want to know how to build a clock. This guide is designed for both.

Chapter 1 is an executive summary that distills every other section of the guide. A reader who only wants the "what" and "why" of risk management could read just this chapter to get an overview of the entire guide.

Chapter 2 is a "getting started" section that explains how to create a risk management program. It presents the policies, tools, and processes needed to create an ongoing risk management program. It describes what is needed to implement and sustain an enterprise risk management program.

Chapters 3 through 8 are quite detailed and describe the steps agency staff can take to manage risks at all levels of the organization. They include tools to be used in workshops to identify and assess risks. They also describe agency-wide practices to compile identified risks and sort them for executive decision making. They conclude with a section on measuring an agency's risk management maturity.

Chapter 9 provides more detail on how risk is being applied nationally and internationally to typical transportation program areas. It summarizes how U.S. and international transportation agencies apply risk management to key programs such as highway safety and asset management, and to traditional business operations such as purchasing and inventory control.

Chapter 10 is a critical review of the state of practice, both in public and private sectors.

Chapter 11 is an advanced section that demonstrates risk management tools, such as Monte Carlo simulation that quantifies risk probabilities.

Chapter 1: Defining Risk Management

Summary

This chapter defines risk, risk management, and the risk management process. It also explains how risk management complements performance management. The guide recommends applying risk management at four levels of the organization: enterprise, program, project, and activity. Finally, it summarizes the risk management process.

Understanding modern risk management requires understanding new vocabulary. Unlike in common usage, "risk" involves more than just threats or hazards. In this guide, risk is defined as follows:

> *Risk is the positive or negative effects of uncertainty or variability on agency objectives.*

This definition holds several implications for understanding risk management. First, risks are not always negative. In modern management frameworks, managing risk is about managing uncertainty, variability, threats, hazards, and even opportunities. All of these can affect organizational objectives. A negative risk could be a flood. A positive one a new technology.

Second, managing risk is about managing performance. All performance objectives face risk, particularly in the complex environments in which transportation agencies operate. Achieving objectives relies on both internal and external factors that are subject to uncertainty and variability. Ignoring those risks is to ignore impacts on performance. If performance management exists to achieve objectives, then risk management exists to identify and mitigate the risks to those objectives.

Third, managing risks is about managing opportunities. This may seem counterintuitive, but few risks equal few rewards. Every organization needs to take risks to achieve its objectives, particularly as public expectations of organizational performance grow. Careful evaluation can lead to well-reasoned risks that produce substantial rewards and accomplishment. Often the magnitude of achievement correlates to the degree of risk. This realization led the World Road Federation to say that risk management could be redefined as "opportunity management."[1] This concept is particularly refined in the world of finance, where risk is not bad, but merely a measure of potential loss or reward.

Definition of Risk Management

Building on that discussion, this guide uses following definition of risk management:

> *Risk management is the cultures, processes, and structures that are directed toward the effective management of potential opportunities and threats.*

Similar to the definition of risk, this definition of risk management reflects several aspects of modern enterprise risk management.

First, the reference to cultures recognizes that optimally, risk management should be ingrained in the daily processes of an organization from high-level strategic functions to frontline daily operations. The Australian state of Victoria has a well-defined and formal risk management policy that emphasizes its use should not be limited to specialists but practiced by staff every day. It defines its culture as "the way we work around here."[2] It recommends that risk management create a culture in which all employees understand risks and are willing to take well-considered ones.

Second, the reference to processes and structures recognizes that risk management is a process-driven framework that includes well-defined steps. Performance management requires structured processes to set goals and direct complex resources to achieve those goals. If risk management parallels and supports performance management, it also requires processes, structures, and formality based on organizational policy.

This guide also emphasizes that risk management should be an active discipline. Therefore, the guide adopts this definition:

> *The risk management process is the systematic application of policies, procedures, and practices to the identification and management of uncertainty or variability on achievement of agency objectives.*

This third definition accentuates the active, continuous nature of risk management. This guide recommends that it be an ongoing process. For instance, updates on risks and how they are being managed could be incorporated into daily briefings, monthly management reports, budget documents, and updates to an agency's commission. Many risk authors say risk management success is unlikely to be achieved by one-off activities or delegation to technical staff. One private-sector author wrote that executives either continuously engage in risk management or they are condemned to routinely practice crisis management.[3] If risk to objectives is constant in a complex environment, then the managing of risk should be continuous.

"Risk is the positive or negative effects of uncertainty or variability on agency objectives."

"Risk management is the cultures, processes, and structures that are directed toward the effective management of potential opportunities and threats."

"The risk management process is the systematic application of policies, procedures, and practices to the identification and management of uncertainty or variability on achievement of agency objectives."

An extensive literature review was completed before this guide was developed. It summarized more than 120 sources, many of them from the private sector, where risk management is more mature and defined. A common theme of the risk management sources was that risk management should be thought of as a hands-on, participatory practice. Inferred by some authors was a shift in definition from emphasizing "risk management" to emphasizing "managing risks." Their inference was to turn the concept from a noun into a verb. Emphasizing the managing of risks highlights the active, participatory nature of successful risk management. When discussion focuses on risk management, it infers that setting up the architecture—or process and structures—is paramount. What many authors emphasize is that the active use of the architecture is most im-

portant.

To summarize, this guide differentiates three concepts necessary to understand the application of risk management.

- Risks are positive or negative things, events, actions, variability, or threats that create uncertainty for objectives.
- Risk management is the architecture for managing risks.
- The risk management process is the active use of that architecture for managing risks.

Clarifying Risk and Risk Management

A precise vocabulary is required for transportation agencies to discuss risk management with policy makers, such as legislators. This is because the terms "risk" and "risk management" traditionally have meant different things to different industries.

Twenty years ago in most corporations, risk management focused on managing insurance costs and claims. The risk manager analyzed workplace injuries and took steps to reduce them. The risk manager also focused on ensuring that smoke detectors were used and that employees wore seat belts while driving company vehicles. Then, managing risks was narrowly focused on managing insurance claims, and most definitions of risk and risk management were tailored to an industry's unique niche.

In the finance world, risk management means calculating the potential variability from different investments. Managing risks involves complex mathematical calculations of probability to determine how much an investment house should pay for complex hedges, puts, and calls to protect itself from unexpected market downturns. Puts and calls allow investors to sell at a price floor or buy at a pricing ceiling, which hedges against excessive losses.

In the insurance industry, risk is the value of an insurance policy and the likelihood that a claim may have to be paid. Managing risks relates to calculating the price of underwriting policies. In the aviation field, risk management focuses on reducing plane crashes, hijackings, and terrorist threats.

These narrow definitions led to the development of another term to describe the broader management of risks to an organization's strategic objectives, or enterprise risk management (ERM). Similar to other publications, this guide adopts this definition:

> *Enterprise risk management is the formal and systematic effort to control uncertainty and variability on an organization's strategic objectives by managing risks at all levels of the organization.*

Managing Risks Complements Performance

The expansion of enterprise risk management reflects the growing expectation that executives need to manage risks to accomplish the organization's objectives. The concept is that risk management is the mirror image of performance management, as Figure 1 shows. Without controlling risks, performance is difficult to guarantee. The two disciplines operate

in parallel, with performance management setting objectives and risk management identifying their potential obstacles. Performance management can be thought of as the drivetrain of an organization, and risk management can be considered a navigational aid. When working in concert, they help an organization achieve its strategic objectives. The disciplines do not compete, but instead complement each other to support strategic objectives.

The concept that it is incumbent upon leaders to manage risks acquired legislative foundation with the passage of the Sarbanes-Oxley Act in 2002. Among other things, it requires corporate executives to adopt sound risk management and disclosure practices to protect investors. Corporations are to manage the risks they take and to disclose those risks to shareholders. The intent is to enable investors to be better informed and to reduce their exposure to corporate bankruptcies, such as occurred with Enron Corp. and WorldCom Inc. The Risk Management Society is an international, nonprofit association of risk professionals and it reports that after these failures, there was an increasing tendency for risk management practices to expand from specialized application at the project or activity level to application across the organization as enterprise risk management.[4]

Figure 1. This figure illustrates the concept that risk management and performance management operate as parallel, complementary disciplines.

Various risk management standards and guidelines cite similar rationales or benefits for adopting enterprise risk management. [5,6,7] Because risk is common, people and organizations have always managed risks informally even if they did not adopt a formal or rigorous risk process. The modern rationale for formal risk management is to acknowledge the universality of risks and systematically adopt processes to identify and manage them. The alternative to risk management is accepting informal, anecdotal decisions and occasional threats, disruption, and setbacks caused by threats or risks in the natural, economic, social, or political environments. The many frameworks for risk generally cite similar benefits, such as risk management results in fewer surprises for an organization, it exploits opportunities, it improves planning and decision making, it protects value, and it increases the well-being of stakeholders. Increasingly, risk management is considered a basic component of sound governance. Much like acceptable accounting and fiscal controls, risk management is expected as a basic corporate competency.

Another rationale for risk management is that the lines between good risk management and overall good management are blurring in today's environment of high performance expectations.[8] Risk management used to be more of a specialty discipline in industry, much

like human resources. Today, financial and environmental regulations create pressures on executives to ensure that their organizations are anticipating and responding to risks. Now, risk management is a core discipline, one that executives need to embrace as a personal and corporate responsibility. In the world of corporate governance, many concerns of running a large organization are being reframed in terms of risk, which means that the role of risk managers and their tools will be increasingly important.

The extensive literature on modern management and performance shows a clear link between controlling risks and increasing an organization's performance. As the consequences of failure increased, so did the importance of managing risks. As the transportation system evolved from stage coaches to canal boats to railroads to commercial aviation, the consequences of risks increased. Executives who failed to identify and reduce those risks increased the chance of their organization's failure to achieve expected performance. The literature reveals a clear evolution from the early writers on quality such as Walter Shewhart[9] and Edwards Deming, who focused on organizational performance, to modern authors such as James Lam[10], who argues that managing risks equates to improving organizational performance and reliability.

As evident in MAP-21, the private sector's emphasis on managing risks is now migrating into the public sector. Although MAP-21 does not present a fully articulated vision of risk management, it incorporates risk principles into provisions for highway safety and transportation asset management (TAM). Section 119 requires states to develop risk-based TAM plans to achieve specific condition targets on the National Highway System (NHS). These provisions require state transportation departments to achieve performance targets and, presumably, to manage the risks to that achievement.

Manage Risks to Manage Objectives

Bernstein[1] contends that modern civilization is in significant part defined by its efforts to understand and control risk. Efforts by modern societies to understand and reduce the causes of disease, crime, and warfare are viewed within the broad context of identifying, analyzing, treating, and monitoring risks to their citizens. Bernstein was a successful investment fund manager and the first editor of the Journal of Portfolio Management. Among his six books is Against the Gods: The Remarkable Story of Risk, which traces risk management from a practice in which similar merchants or tradesmen protected each other against catastrophic loss to the evolution of sophisticated mathematical-based risk management strategies. The development of mathematical models of probability and statistical analysis by such well-known figures as Bayes, Pascal, and Fermat provided the mathematical foundations for quantified risk management.

Today, risk management is a broadly applied field that is specialized by profession. Risk managers are common in fields as diverse as retailing, in which they focus on reducing inventory theft; aviation, in which they focus on safety; and investing, in which they focus on providing guaranteed returns and hedging against significant losses. A central premise of many authors is that sophisticated management and responsible social leadership are impossible without managing risks.

Enhancing Decision Making by Evaluating Risks

Another rationale for risk management is to enhance decision making by realistically stating the internal and external risks that face a performance objective. The magnitude of risks increases as agencies develop more ambitious objectives that involve more complexity and longer horizons. A simple example relates to the risks state agencies face when they devel-

op MAP-21 highway safety plans. As the agency expands its ambitions to achieve and sustain crash-reduction targets for several years, the external and internal uncertainties grow significantly. As performance objectives increase in complexity, managing risks to those objectives grows in importance and the tradeoffs become more complex.

Risk management, asset management and performance management become linked when decision makers weigh short-term investment requests with long-term risk-reducing investment options. In the short term, a worst-first investment may seem to reduce the most immediate performance risk. However, over the long term an investment in preservation today may reduce much larger performance risk in the future. The linkage of risk, asset and performance management becomes more apparent when long-term performance horizons are used. When agencies adopt a 10-year asset management horizon and try to sustain asset conditions for the lowest cost over the long term, the risks of not investing in preservation and maintenance becomes clear. The lack of investment in maintenance creates a much greater investment and performance risk in the later years of the long-term asset management plan.

The credibility of such ambitious plans lies in part on the degree to which they acknowledge the risks they face. The plan's success requires cooperation among many transportation, law enforcement, education, and emergency-response agencies. Years of consistent funding and coordinated efforts by the various parties will be required. No one agency can guarantee the success of the safety plan. As a result, when the agency acknowledges the risks and uncertainty facing the plan, the credibility and reality of the plan increases.

Public Expectations for Managing Risks

The New South Wales Treasury (2012) says in the Risk Management Toolkit for New South Wales (Australia) Public Sector agencies:

"In a globally connected world, both the types and magnitude of risk we face are increasing, while our tolerance for ineffective risk management is diminishing. Simply put, many more things can go wrong and with more far-reaching consequences. At the same time, the community increasingly expects public sector agencies to manage these risks to minimize any negative consequences.

But increased uncertainty in the world today can also offer possibilities. Recognizing and responding to opportunities, as well as effectively managing for things that could go wrong, will not only support the success of your agency in meeting its objectives but also ensure that your agency remains relevant and resilient into the future."

MAP-21 reflects the influence of Australian and British risk management practices on U.S. transportation laws. Statutes in the Australian states of New South Wales, Victoria, and Queensland all rely on risk management to enhance long-term decision making. Their statutes require transportation departments to adopt strategic planning, performance management, accrual accounting, and risk-based asset management as a suite of good-management practices. This quartet collectively results in agencies needing to do the following:

- Identify strategic objectives.
- Use performance measures and performance management to achieve those objectives.
- Rely on accrual accounting and long-term financial plans to get ahead of the curve on any looming, unfunded financial needs related to achieving those targets.
- Use risk-based asset management for the long-term, sustainable performance of infrastructure.

These practices were examined by scanning teams from the Federal Highway Administration (FHWA) International Technology Scanning Program in 2005, 2010, and 2012.[11,12,13] All three scan teams acknowledged the benefits of risk-based performance management and reported on its contribution to agency performance and decision making. One team developed the graphic in Figure 2 to illustrate the integral role that risk management can play in supporting asset and performance management. The graphic illustrates risk management as an enabler for performance management and asset management to achieve the agency's strategic goals. Both performance management and asset management objectives can be stifled by risks and uncertainties.

Failing to acknowledge, measure, and manage these uncertainties is to overlook obvious risks that affect the credibility and success of the agency's decisions. The scanning reports explained how the Australian and British transportation agencies had embraced risk management as an enabler of their performance and asset management decision making.

Allocating Scarce Resources

Another function of risk management is to help allocate scarce resources. Nearly all transportation agencies are unable to afford all the legitimate needs they face. By restating decisions in terms of risk, agencies are able to clearly communicate why they have invested scarce resources in some projects and activities but not others. By clearly stating their performance objectives and risks, they can better define an acceptable risk and they can better plan for future budgets.

Figure 2. Risk management can be an enabler that supports asset and performance management.

Agencies have used risk-based decisions for decades to allocate resources, but those decisions are often not discussed in terms of risk or the risk tradeoffs are not formally documented. Nearly all transportation agencies seek higher condition levels for high-volume assets because poor conditions on those facilities increase the likelihood of crashes, congestion delays for more users, or greater impedance to the movement of goods and people. As agencies develop risk-based asset management plans, they can use risk to explain why investments need to be greatest on higher functional classes to respond to the greater risks those facilities face. Before MAP-21's expansion of the NHS, it included 162,944-miles of the nation's key corridors. In 2008, the NHS included only 4 percent of the nation's total route mileage and 6.7 percent of total lane miles, but it carried 44.3 percent of vehicle miles traveled (VMT).[14] The NHS also carried 75 percent of heavy truck traffic and 90 percent of tourist traffic.[15] Only 19.5 percent of the nation's bridges are on the NHS, but they comprise 49.2 percent of the nation's total bridge deck area. From a risk-based standpoint, poor conditions on the NHS create significant risks to the safe movement of goods and people. If agencies need to reduce service levels on other routes to preserve the NHS, risk management provides a decision framework.

Conversely, among the routes with the highest crash risks are rural, relatively low-volume two-lane roads, particularly at night. Because many crashes on two-lane routes are widely dispersed, investing scarce safety funds into spot locations may not provide significant benefits. This led FHWA and many state transportation departments to encourage risk-based systemic safety investments to reduce the risk of lane-departure crashes.[16] Strategies include systemic treatments to shoulders, lane delineation, advanced warning signs at curves and intersections, improved lighting, and other broadly applied treatments. The logic of these approaches can be used to explain the risk-based investments agencies are making to improve system-wide safety, as opposed to investing only in locations where crashes already have occurred.

Identifying and Mitigating Threats

The emphasis on risk management as a complement to performance management and decision making is not intended to diminish the traditional role risk management can play in reducing threats and hazards. With society's concerns about highway safety, terrorism, climate change, and other threats, risk management can provide an additional framework for prioritizing hazards. More detail on managing risks from external threats and building agency resiliency are in Chapter 9.

An example of how risk management can assist in the assessment of vulnerabilities from climate change is FHWA's *Climate Change and Extreme Weather Vulnerability Assessment Framework*.[17] It incorporates a risk-based approach to assessing an agency's vulnerability to flooding, storm surge, severe weather, and other impacts from climate change. The Washington State Department of Transportation (WSDOT) piloted the framework and developed a risk-based analysis of how climate change could affect its geographically diverse state. It examined issues such as sea level changes and storm surges along the coast, mountain stream flooding and slides caused by increased rainfall, and increased fires caused by drought.[18] WSDOT illustrated the utility of risk management as a framework for climate-impact assessment.

Austroads, the transportation association of Australia and New Zealand, provides a highway safety manual that uses the International Organization for Standardization (ISO) and Australian international risk guidelines. It illustrates how standard risk frameworks lend themselves to identifying, mitigating, and monitoring threats and hazards to motorists, pedestrians, bicyclists, and other groups.

Risk-based processes for assessing the scour potential of bridges are well defined.[19] An international scanning report[20] documented how more sophisticated risk-based inspections and design can reduce risks of bridge failure, over-design, and over-inspection. It explained how some European agencies use risk to allocate scarce bridge-inspection resources. Newer, low-risk bridges may be inspected fully every several years to allow inspection resources to be reallocated to more frequent, in-depth inspections of high-risk, high-volume structures. Inspecting every bridge on the same cycle may expend resources where they are not needed and consume resources needed for monitoring higher-risk structures.

The Levels of Risk Management

Most risk frameworks recommend that risk be managed at multiple levels. This guide includes four levels of risk management, although the levels can vary by the framework adopted. The four, illustrated in Figure 3, are enterprise, program, project, and activity.

Managing risks at multiple levels is emphasized for several reasons. First, strategic objectives usually cannot be achieved without coordinating many functions throughout the organization. Strategic objectives generally are complex, multifaceted undertakings that require executing steps at many levels. Hence, it often is not possible for executives to ignore frontline functions and expect strategic objectives to be achieved.

Also, severe problems at the activity or project level can escalate to become a strategic risk. If a critical project—such as deployment of a new software program—fails, it can create cost and controversy that arise to a strategic risk. A cost increase on a project can be so severe that it affects the entire program of projects, creating a strategic risk. An episode of malfeasance in an organization can create substantial reputational risks that executives need to address to ensure the organization retains its credibility. In keeping with the advice that managing risks should be an active undertaking by all executives, it is advisable to address risks throughout the organization.

Enterprise risk management already has been defined as "the formal and systematic effort to control uncertainty and variability on an organization's strategic objectives by managing risks at all levels of the organization." As Figure 3 shows, enterprise risks generally are the responsibility of senior executives and policy makers. Several risk management authors advise senior executives to make risk management part of their routine management processes. Once a risk process is in place and ongoing reporting of risks is established, the executives monitor their risk register and risk-mitigation processes much like the captain of a ship monitors activities on the bridge. The executive and his or her team scan the horizon for new risks, ensure that identified risks are being managed, and monitor that risk strategies are working. Exceptions at the program, project, or activity level are reported to the executives if they become significant enough to be potential enterprise risks.

Figure 3. The levels at which risk management is practiced.

This guide uses the Project Management Institute's definition of a program:[21]

> *A program is a group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually.*

An example is a transportation agency's bridge or pavement program. It may consist of a random collection of bridge and pavement projects, but in a performance-based organization it more likely represents a strategic collection of preservation, maintenance, rehabilitation, and replacement projects intended to achieve and sustain condition targets for a reasonable life-cycle cost. The program includes ancillary support functions, such as operation of a pavement management system or data-collection activities, critical to success of the program objectives.

A program manager is the primary person responsible for identifying, measuring, and managing the program risks. The same steps for managing risks shown in Figure 4 occur at every level. The difference is the extent and scope of risks to be managed. A typical transportation agency would manage multiple programs, such as an information program, various infrastructure-class programs for pavements and bridges, project delivery programs, environmental compliance programs, and safety programs. Each would have its own risk manager who monitors the program risks and reports to the enterprise level if serious risks arise that could affect the program objectives.

Programs generally exist to achieve organizational goals and objectives. Failure in a program is likely to ripple through an organization's strategic goals and objectives.

A project is defined as follows:
A temporary endeavor undertaken to create a unique product, service, or result.[22]

Managing risks to projects is the most widely practiced form of risk management in most transportation departments. It generally involves identifying and managing risks to project cost, scope, and schedule. Increasingly, however, agencies are also concerned about managing compliance risks. These could be risks to environmental compliance commitments or commitments to adjacent property owners to reduce noise and other construction impacts. The Minnesota Department of Transportation (MnDOT) also includes quality as a basic project risk it seeks to control.

The final level of risk is at the activity level. An activity is defined as follows:

> *A coordinated set of ongoing actions taken to support projects or programs.*

The activity level is not included in most risk management frameworks. However, it is included in this guide because of the large number of important activities that transportation

Portfolio Risks

The Project Management Institute recognizes another level of risk management between the strategic and the program: portfolio management. It defines a portfolio as a collection of projects or programs and other work that are grouped together to facilitate effective management of that work to meet strategic business objectives. Examples are bridge and pavement programs included in an asset management portfolio or all the information technology equipment, resources, and personnel in an information portfolio. Although agencies could manage at the portfolio level, the concepts are so similar to program management that this guide does not address portfolio management.

agencies perform. Functions such as counting traffic, updating asset inventories, conducting winter operations, maintaining drainage structures, and maintaining traffic signals are critically important. All face numerous risks and uncertainties that, if they become serious, can affect projects, programs, and conceivably strategic objectives. In one 2014 case, a state transportation agency is under a Federal Department of Justice agreement to clean and repair catch basins to comply with storm water runoff regulations. The lack of routine catch basin maintenance has arisen to be a costly, strategic risk that diverts resources from other programs and other strategic objectives. In this case, the risks in a day-to-day activity have become so severe they endanger other strategic goals of the agency. Breakdowns in many activities hold the potential to affect strategic objectives. Breakdowns in right-of-way acquisition processes can delay project and program delivery. Environmental permitting can impede both project delivery and maintenance activities. Activities as routine as stocking parts can become strategic impediments if they reduce the number of operable snowplows during the winter. At many levels, the impact of breakdowns in activities can create project, program, and even strategic risks.

Also, managing risks to activities is relevant to transportation agency personnel. Many are employed at the activity level. By presenting strategies for managing risks to activities, the guide illustrates how risk management can be relevant and useful to personnel at every level of an organization.

The Risk Management Process

This guide uses as a basic risk management process the one published by ISO in 2009. ISO is a Switzerland-based federation of national standards bodies that organizes subject matter experts from the public and private sectors to develop, critique, and adopt internationally recognized professional standards.

The ISO process has been adopted by Australian and Canadian associations and is widely recognized in the United States. Its conceptualized approach, shown in Figure 4, illustrates its similarity to other “plan, do, act, check” frameworks developed since the days of Shewhart in the 1930s. It bears similarities to total quality management, Six Sigma, Lean, and other process-improvement frameworks. Like those frameworks, the ISO risk management process starts with a recognition of the organization’s strategic objectives and focuses an organization’s attention on achieving them through a continuous review and improvement process.

The ISO Concepts

The ISO process in Figure 4 represents the concepts and considerations that comprise the risk management process, not necessarily discrete steps that are used in all instances. In some cases, such as a transportation agency commission adopting its first risk management program, users may methodically step through every stage of the ISO framework. In other cases, such as an activity manager updating his or her risk management program, users may not proceed in lockstep with the Figure 4 components. Although each concept is important, the guide does not suggest that the rote following of each step is required in all instances. Practical judgment is recommended.

Establishing the Context

The first step in the ISO process is to acknowledge and identify the context of the organization.

- What is the organization's or work unit's mission?
- What are its challenges?
- What is changing in its environment?
- What authority and resources does it have?
- What objectives has it identified or have been assigned to it?
- What are its legal, political, and social environments?

Risk management must be practical to be effective. It must address the pressing challenges and opportunities of the organization or it will not be relevant. Throughout, this guide emphasizes that risk management exists to help organizations achieve their mission and objectives, so the first step is to document those objectives and the context in which the agency is trying to achieve them.

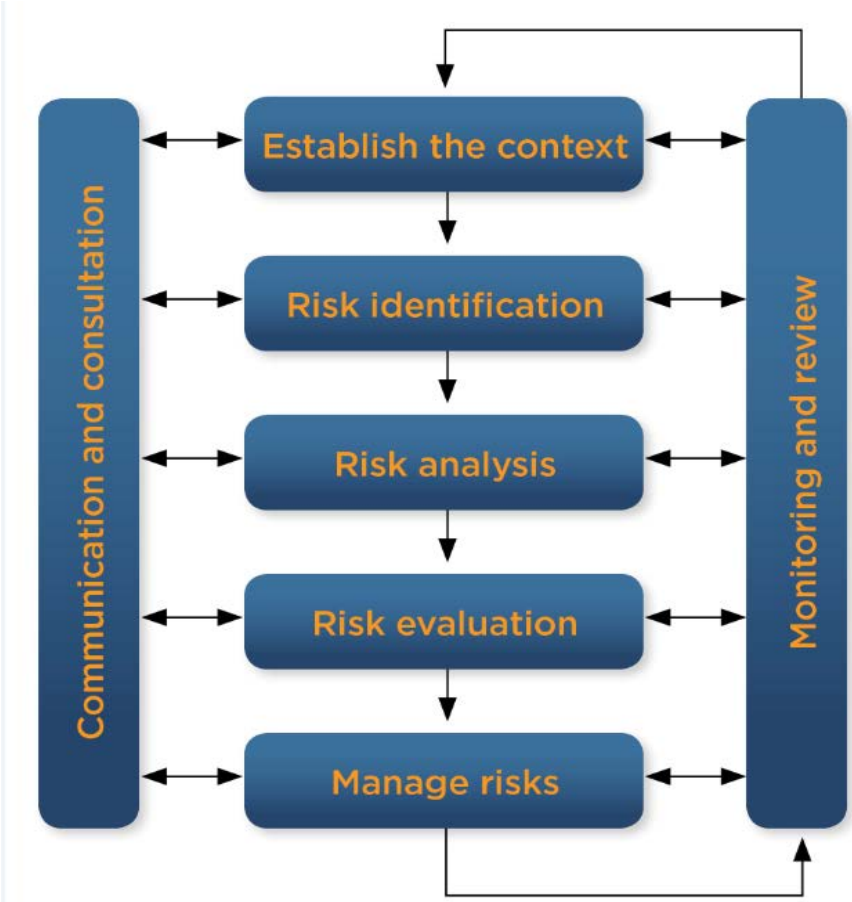


Figure 4 The ISO process

Another early step is to identify the organization's risk appetite. This can be either a qualitative or quantitative expression of the degree of risk an agency is willing to accept. The appetite varies by type of risk.

An example of a qualitative risk appetite is expressed by England's Highways Agency, which has very low tolerance or risk appetite for fraud, theft, or malfeasance. Employees are instructed to take few risks that expose the agency to them. However, it has a much higher risk appetite for pursuing opportunities through public-private partnerships (PPP) and innovative contracting. Although PPPs and innovative contracting bring risk of potential costs or losses to the agency, they also bring substantial possibility of gain in leveraging new resources or providing new projects to the public. Although both PPPs and theft provide a chance for loss of public resources, PPPs offer a possibility of significant gain and lack the potential reputational risks that come with incidents of theft or malfeasance. The Highways Agency risk policy encourages employees to take risks, but not to take significant risks in areas where the risk appetite is low.

An example of a quantitative risk appetite is the New Zealand Transit Authority's policy of keeping the miles traveled on low-friction routes to no more than 2 percent of its highway network. Low skid numbers increase the potential risks for motorists who face increased stopping distances and less pavement friction in curves. The agency is willing to tolerate the risks posed by 2 percent of its system having poor skid conditions, but not more than 2 percent.

The expression of the risk appetite reflects the policies, philosophies, objectives, and legal requirements the agency faces. The appetite is used later in the guide as a threshold to measure which risks to tolerate and which to treat.

Risk Identification

Risk identification and the next two steps, risk analysis and risk evaluation, are grouped under the general title of risk assessment. Each is discussed individually here with more detail in Chapters 4 and 5.

In the risk identification phase, the organization casts a wide net to compile all the credible risks it can identify. Depending on the level of the analysis, these could be risks to the enterprise, programs, projects, or activities. Ideally, risk managers at all levels of the organization identify their risks, and decision makers classify them and assign them to the appropriate risk managers.

This guide's chapters on risk identification, risk analysis, and risk evaluation discuss tools and techniques to draw out a comprehensive list of risks from staff. Typical strategies to identify risks include conducting workshops and surveys, organizing groups of subject matter experts, reviewing performance reports, and reviewing direction given to the organization by policy or executive groups. The intent at this phase is to identify a comprehensive set of risks inside and outside the organization. As the ISO standard notes, if risks are not identified, they cannot be managed.

Risk Analysis

Risk analysis involves several steps. First is identifying the root cause of risks. The root cause plays a significant role in later stages when an organization evaluates risks and decides if and how to treat them.

A second step in this phase is to identify the possible negative and positive outcomes. The type of consequence and its magnitude will have a major bearing on whether mitigation steps will be taken and to what degree.

A third step is to estimate the likelihood of the risk occurring. This likelihood can be developed by extrapolating from past occurrences, expert judgment, or estimates of likelihood.

The consideration of all three factors provides the input for the next phase, risk evaluation.

Risk Evaluation

Based on the root cause of the event, its possible impact, and its likelihood, the organization can develop a rank-order list of risks. The risks can be prioritized based on the combination of impact and likelihood.

In this phase, risk managers evaluate and rank the risks based on the criteria of the agency. Evaluation and ranking can be conducted several ways. Risks can be categorized by how they affect enterprise, program, project, or activity objectives. They can be ranked according to the risk they pose to compliance with statutes or other nonnegotiable requirements. They can be listed in rank order and prioritized by their impact and likelihood.

Risk Management

In this phase, the guide differs from the ISO framework, which addresses "treating" risks after they have been identified and evaluated. The guide expands this step to "managing" risks because the response could involve actions other than treatment. Some risk guides and frameworks also refer to this stage as "risk response."

In this phase, the agency decides if and how to react to the risk. It may decide that the negative consequences are low or unlikely, so the agency will tolerate or accept the risk. The agency may also see the risk as an opportunity and try to capitalize on it.

In this phase, five typical options exist:

Tolerate: The agency could decide that the risk is low, the chance of occurrence is unlikely, or the risk is outside of agency control. In these cases, normal monitoring or treatment is the only option. Examples include the risk of Congressional failure to fund transportation programs. The agency may monitor the risk and communicate its potential consequences, but it is forced to tolerate the risk. Another example is the risk posed by a potential rock fall location that presents a moderate risk, but would be costly to mitigate. The agency may decide to tolerate this risk while continuing to monitor the site.

Treat: If treatment is possible and its benefits outweigh its costs, the agency could decide to act on and mitigate the risk. This could be done many ways, depending on the type of the risk. A high-risk rock fall location may be treated. A high-risk bridge may be instrumented to improve monitoring or it may be repaired or replaced. A new organizational policy and procedure may be adopted to reduce a perceived risk of theft or malfeasance. Depending on the degree of risk, treatment cost, and perceived success of treatment, the agency may decide to take action to treat the risk.

Differing Terminology

This guide uses 5Ts as an alliterative, easy-to-remember set of risk responses. Other frameworks use different risk-response terminology. ISO includes seven risk-response options, while the Project Management Institute (PMI) includes three negative risk or threat responses and three positive response options. A National Highway Institute (NHI) course includes four threat responses and four opportunity responses. Chapter 7 includes some typical alternative risk-response terminology in addition to the 5Ts. It is less important which terminology an agency adopts and more important that the agency uses terminology consistently.

Transfer: Transferring risk is common in the private sector, but less so in the public sector. The most common way to transfer risk is to buy insurance. Individuals and businesses transfer risk continuously by purchasing insurance on their homes, vehicles, and even their lives. Insurance for transportation agencies is less common but is used occasionally. Some more common risk-transfer tactics include requiring contractors and consultants to provide performance bonds, owners protective liability and professional liability insurance. In a design-build project, some design risks are transferred to the contractor. In a mature risk management program, an agency looks for cost-effective ways to transfer risks.

Terminate: Another risk-response option is to terminate the risk by stopping a practice or eliminating the source of the risk. Systematically replacing timber bridges with concrete or steel structures represents an effort to terminate the risk posed by timber structures. Replacing buried guardrail ends with crash attenuators terminates the rollover risk posed by buried rail. Although some risks can be terminated, many cannot. A private contractor may decide not to provide snow and ice services because of the risk that the investment in equipment and personnel will not be returned in years with little snowfall. A transportation agency cannot eliminate such risks. In fact, society created the organization to take such risks. In the public sector, risks inherent in mandated activities many times cannot be terminated.

Take advantage: A fifth option is to take advantage of the risk. This can occur after an agency has carefully evaluated a risk and decided that its potential upside exceeds the likelihood of its negative consequences. An example is an agency deciding to embrace design-build contracts or PPPs or adopt a new construction material. Every new process brings some risk, but it may be offset by greater rewards. Although it sounds counterintuitive to think of opportunity as a risk, the two are closely related. The result of a risk analysis is often to seize on an opportunity or take advantage of the risk.

Communication and Monitoring

The ISO standard and many authors emphasize the continuous nature of effective risk management. This continuous involvement takes two general forms: communication and monitoring.

The continuous nature of communication and monitoring reflects two key facts. First, a large number of internal and external stakeholders affect agency risks and communicating with them is necessary. Second, risks are generally fluid and changeable. Continuous monitoring occurs to determine if risk factors remain as expected or if circumstances increase or decrease the risk likelihood.

These elements—communication and monitoring—reflect the emphasis on thinking of risk management as a verb, not a noun. The steps reflect the agency's active monitoring and managing of its risks and the effectiveness of its risk responses. A heavy rain may turn a moderate rock fall risk site into a high-risk one. A sudden spike in bid prices should prompt a review of whether inflation risks are rising and will hurt the larger construction program. As discussed in this guide, the risk management framework assumes that the agency will identify policies, personnel, structures, and processes to continuously monitor and effectively communicate about the risk environment.

Level of Effort for Enterprise Risk Management

Leaders of fiscally strapped agencies may be reluctant to assume additional costs for enterprise risk management. The discussion in this guide of continuous monitoring and comprehensive risk identification may lead to the assumption that large staffs are needed for enterprise risk management.

Practitioners in U.S., Canadian, British, Dutch, and Australian agencies say, however, that only a few key staff are needed to support an enterprise risk management effort as long as the leadership embraces it and staff throughout the organization incorporate it into normal management activities. Risk managers at FHWA, England's Highways Agency, TransLink in Vancouver, British Columbia, and Australian agencies compare the level of effort to that of any good management practice, such as managing to performance. Although performance management may include central staff to measure agency-wide performance, the large majority of effort is incorporated into the everyday jobs of managers. Just as managers routinely set priorities, measure performance, and manage staff, they would add risk reporting as a regular management duty.

The coordinator of England's Highways Agency reported that his nationwide organization has an active risk management program, but it does not have a full-time risk manager, although it plans to recruit one. Central staff who coordinate performance management also support and coordinate the agency's risk management effort.[23] The effort produces monthly reports to the Highways Agency's board that are part of larger corporate updates. An initial flurry of activity was needed several years ago when the agency wrote its policy and established its risk management processes. Now, coordinating the risk management program is a part-time effort of the central performance-management staff. They coordinate the identification and management of risks among the many divisions. However, even at the divisional level, risk management is a common management task ingrained among others, so it is difficult for the agency to identify the total cost of its risk management effort. The agency does not perceive it as a burdensome effort, but as one managers are expected to absorb as part of their normal due diligence.

The Dutch national transportation agency, Rijkswaterstaat, or the Ministry of Infrastructure and the Environment, said it could not easily estimate the cost of its enterprise risk management program because it is so integrated into the daily activity of staff and is not a stand-alone task.[24] Rijkswaterstaat staff report that they use risk considerations in many areas of management, as well as with infrastructure management. Considerations of risk are so ingrained that they have difficulty extracting the costs of risk management from other routine management activities.

The FHWA enterprise risk management staff also report that the costs of its enterprise risk management efforts are such a small fraction of the agency budget and are so ingrained in normal management activities that it is difficult to estimate the costs.[25] The risk efforts require less than one full-time staff equivalent for the entire agency of about 2,600 people. A Washington-based staff member coordinates the risk effort along with performing other duties. Sixty-seven units in the FHWA headquarters and state divisions produce risk registers. While many staff are involved, the annual effort for each staff person probably is less

than a day or two. They meet annually to produce their risk register and periodically throughout the year to update it.

TransLink is Metro Vancouver's regional transportation authority. It operates regional transit, highway, cycling and commuting options as well as Intelligent Transportation System programs. It has about 7000 employees, of which about 5800 are bus or rail operators. It has a mature, comprehensive enterprise risk management program that requires the part-time efforts of three staff. [26] Those three employees also contribute to strategic planning and performance management functions. The TransLink leadership views risk management as an essential function but not one that consumes substantial resources. They describe a system in which three central staff work with the agency staff at key points in the annual performance cycle of reviewing past performance, developing updated annual work plans and incorporating risk management into the work plans. The central staff assist the agency units with coordinating workshops, facilitating meetings and helping work units complete performance and risk plans. Those plans matriculate up through the agency to unit heads, division heads and ultimately to the chief executive and board. The role of risk management staff are to facilitate training, risk analysis, develop risk registers and overall program assistance. The bulk of the risk efforts are deeply ingrained into the management planning and performance review of the individual work-unit managers. TransLink officials said the risk management level of effort is not viewed as extensive or onerous because it is such an integral part of the agency performance management process.

A former Minnesota Department of Transportation executive who initiated that agency's risk program also said the effort did not require extensive staff resources. No more than three staff members were focused on supporting the effort while the largest effort occurred when staff and managers identified and addressed risks as part of their normal managerial duties.

A paradox arises when describing enterprise risk management. It sounds complex because it reaches throughout the agency. However, the executives say in concept and practice it does not have to be. One said to be successful with risk management executives should not make it more complicated than it really is. At its core, it involves asking knowledgeable stakeholders what risks surround the agency's objectives and what steps they should take to manage them.

Relying on Risk Management to Improve Performance

The executives contacted consistently reported that risk management improved their agencies' performance by supporting strategic planning and performance management. "It basically aligns the corporation and all the subsidiaries with the strategies of the company and the board," a Translink official summarized. "When you don't have a strategic plan everyone goes off in different directions. This way it zeros in on the top risks of the organization." TransLink officials emphasized that risk management is a not separate function but rather a way of doing business that permeates from the board to garage floor. "It is not something that is a task to do but is embedded in your organization as part of your culture." They described risks as the "things that keep you up at night" and the management of them as the natural task of every manager.

The agency began in 2006 to implement risk management but renewed emphasis came in 2008 with a government-directed reorganization of the agency's board that brought in private sector board members. The corporate executives immediately asked to see the agency's risk registers because the managing of risks is such a basic expectation in the corporate world. Now, the chief executive provides the board a performance and risk update at every board meeting. The managing of performance and risks to that performance are considered a basic management practice at TransLInk.

The FHWA representatives reported that risk management serves as an effective communication tool for improving the management of objectives. It provides a means to communicate consistently across the organization about what are the threats and opportunities facing the agency. The FHWA staff described enterprise risk management as a key component of strategic planning and management. Although costs and benefits are difficult to measure precisely, the FHWA staff compared the question of "what is the benefit of risk management" to "what is the benefit of having a vision and goals for your organization? If you have goals, you have risks to those goals and to be able to describe those risks is important."

The England Highway's Agency staff describe a similar set of benefits for its risk management program. It supports performance and helps to heads off performance obstacles. When some new issue arises, they ask "why didn't we see this coming?" "What precautions did we put in place and why didn't they work?" Like any program, the risk management effort can grow stale when it is not regularly updated but when used effectively it keeps the organization focused upon the issues that could derail its success.

A former Minnesota DOT executive [27] reported he initiated risk management there to manage risks, facilitate communication across a large, diverse department and to increase collaboration. The goal from the beginning was to integrate management of risks into the agency's extensive strategic planning and performance efforts, not to have risk management as a separate function.

He described risk as a lens through which decision making could be improved. The agency faced an expensive, controversial rebuild of a complex interchange that raised community concern, a high price tag and a lack of approval by FHWA. The agency re-thought the project in terms of which movements in the interchange created the highest risks to mobility, safety, costs and neighborhood impacts and scaled back the project to only those elements. By recasting the analysis of the interchange to focus only on its highest risks, the cost fell significantly and community and FHWA approval was secured. He sees one of the unrecognized benefits of risk management as lowering agencies' backlog of unmet investment "needs." Just because an existing facility may not meet some current design or operational standard it can be categorized as a need that leads to huge backlogs of investment that are so large as to discourage legislators from trying to address them. When the agency re-evaluates these backlogs in terms of which create the greatest risk, a smaller, more manageable list of critical needs emerges and is far easier to address.

Adding a risk management focus helped improve decision making in many aspects of MnDOT. It contributed to identification of risks that could impede delivery of the overall program, it encouraged management of risks to projects and from a programmatic level it helped to reduce the perceived backlog of "need" to a more realistic, risk-based assessment of critical capital priorities.

Long horizons, complex goals face risks

The MAP-21 requirement for states to develop asset management plans illustrates an example of how increasingly longer planning horizons and more specific targets raise more performance risks. The asset management plan regulations are likely to require states to set performance targets for at least bridges and pavements on the NHS for the next 10 years. For an average state, achieving these targets will involve the following:

- Forecasting performance of thousands of bridges and lane miles of pavement 10 years into the future
- Estimating how much revenue will be allocated in the next two federal transportation acts and the next five state biennial transportation budgets
- Estimating the performance of existing assets and the effectiveness of planned treatments
- Assuming the cooperation of hundreds of local governments that share responsibility for many assets

As the plan's horizons extend, its complexity increases, and the participants multiply, the risks to achieving the targets in the asset management plan significantly expand. Nearly every aspect of a complex asset management plan faces risks related to planning, information, performance, evaluation, and budgeting.

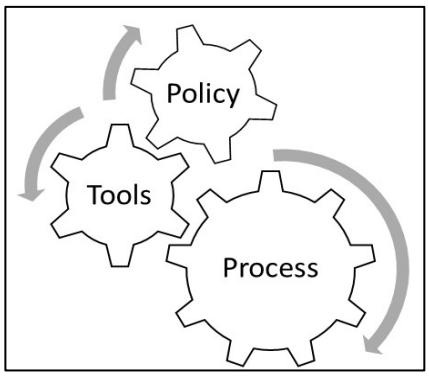


Figure 5. Drivers of risk management are its policy, tools, and integration into agency processes.

Chapter 2: Establishing the Risk Process

Summary

Chapter 1 describes the "what and why" of risk management. This chapter provides the how. It proposes three essential elements shown in Figure 5: 1) An emphatic policy stating the agency will adopt risk management; 2) A set of tools enabling staff to practice risk management, and: 3) Integration of risk management into key agency processes. The premise is that agencies won't be successful without all three. The chapter also includes a checklist of items needed to establish an enterprise risk management program.

Essentials for ERM: Policies, Tools, and Processes

Many professional associations, governments, and business-consulting firms provide risk management frameworks or guides. More than a dozen government frameworks were reviewed as background for this guide.[28,29,30,31,32,33,34,35,36,37,38,39,40] Of particular relevance are ones for managing risks in transportation agencies. Such guides exist in England, several Australian states, New Zealand, and MnDOT. The guides and frameworks demonstrate considerable consistency in describing how to create a robust risk management program.

All the guides say senior leaders and frontline managers should ingrain managing risks into the business processes and decisions of an organization. The international guides and frameworks stress that risk management should not be reduced to a list of steps that are routinely checked off. Instead, consideration of risks should be a driver for executive and staff decision making. Risk assessment should be a part of business processes, including planning, programming, design, construction, information analysis, maintenance, highway operations, and other functions. As each function pursues its objectives, it should identify and manage the risks to those objectives.

Most risk management guides and frameworks implicitly or explicitly recommend three major components for risk management success:

- Base risk management in policy.
- Create tools for employees to understand risks and succeed in managing them.
- Integrate risk management into key processes that ingrain the managing of risks in both strategic objectives and everyday tasks.

Creating a risk-and-performance-based organization involves significant change management. The policy, tools, and process trio can create an official, self-reinforcing series of in-

fluences that establish the legitimacy of risk management, remove knowledge or participation barriers by providing tools and training, and require employees to participate in the risk management process on a continuing basis. The trio of policy, tools, and process can reduce the chance that managing risks remains an isolated checklist function performed only occasionally when required by a management deadline.

Some change-management authors[41] note that the degree to which an organization adopts a new innovation such as risk management relies on three factors:

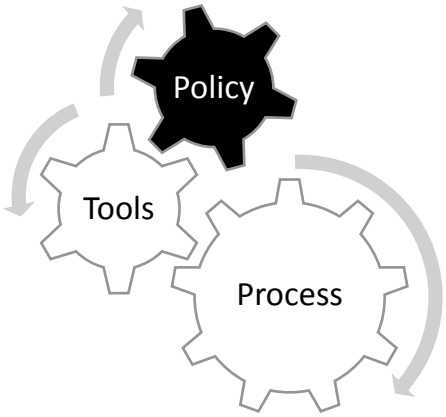
1. The degree to which leadership emphasizes the change
2. The centralization, complexity, and cohesiveness of the internal management structures for accepting direction
3. The degree of outside influence and the organization's openness to that influence

The adoption of policies, tools, and processes attempts to address all three factors. The policy and leadership engagement emphasizes the importance of risk management. The tools give employees the means to identify and manage their risks, and the process engages the internal management structures. External reporting of risks to legislators and FHWA increases the outside influence that encourages the agency to continue managing its risks.

This chapter examines the adoption of the policy, the development of the tools, and the integration of risk management into agency processes.

Step 1: Adopt a Risk Management Policy

A key first step is for the agency director, commissioner, or commission to issue a clear policy stating the agency will adopt and ingrain risk management into its strategic planning and performance management processes. The policy can cite the many benefits of risk management and build on them to explain the imperative to adopt a risk management framework. The following are among the benefits frequently noted in risk management policies:



Enhancing performance: By clearly identifying the risks and uncertainty facing an agency's objectives, the agency can better understand the steps needed to ensure success.

Increasing credibility: Every public organization relies on outside stakeholders for its success. Legislators must appropriate resources, suppliers must produce the inputs, the public must support the agency's objectives, and regulatory agencies must approve its actions. Risk management acknowledges the role of these stakeholders and demonstrates how the agency cannot single-handedly achieve its objectives.

Increasing transparency: A risk analysis can explain an agency's rationale for why it takes some risks and avoids others. A documented risk analysis illustrates that the agency has

considered the risks and rewards of an action and proceeded based on the best available information.

A checklist to establish an enterprise risk management program.

1. **Establish in policy that the agency will adopt enterprise risk management**:
   a. Assign strategic or agency risks to the director.
   b. Incorporate strategic risks in key policy documents.
   c. Assign program risks to program owners.
   d. Assign project risks to project managers.
   e. Assign activity risks to activity owners.
   f. Articulate the agency's risk appetite or threshold.
2. **Create tools enabling employees to manage risks**:
   a. Create a risk unit and/or appoint a chief risk officer.
   b. Provide training.
   c. Develop an agency risk manual or guide.
   d. Create risk measurement tables and risk registers, which are simple tools for evaluating risks.
   e. Create a risk website or other repository for the risk effort and products.
3. **Integrate risk management into agency processes**:
   a. Set the priorities and context for managing agency risks.
   b. Develop an annual cycle for the risk process and the update of risk registers.
   c. Create an ongoing communication and monitoring process and cycle.
   d. Integrate risk management into critical agency processes, such as developing the budget, long-range plan, State Transportation Improvement Program (STIP), and annual work programs.

Performing due diligence: An agency that does not actively identify the risks to its stakeholders or objectives is more subject to criticism that it was negligent. Risk management can provide some legal defense as well as provide defense against criticism that the agency was negligent in considering risks that should have been self-evident.

Providing value: Most guides emphasize that risk management increases value by allowing an agency to neither over-protect nor under-protect against risks. Accepting reasonable risks can provide increased rewards to the public, such as may come from a successful new product or process. Similarly, adopting well-reasoned risk treatments can reduce future costs to the public.

Protecting safety and public well-being: The best-understood risk management rational is to protect against and prepare for threats. A well-planned emergency response plan can be an effective risk management strategy for mitigating the risks of hurricanes, floods, blizzards, and other natural disasters. Similarly, a risk-based rock fall program or roadway-

flooding program can increase public safety and the resiliency of the transportation network.

Sharing responsibility: Transportation agency officials in Australia added another reason for adopting risk management, which is the sharing of responsibility for accepting unavoidable risks. They said when risks are formally documented in budgets or other required plans the agency is informing the executive and legislative branches of the risks inherent in the undertaking. Acceptance of the budget or plan confers shared acceptance of the risk by the agency and the executive branch and the legislature. By noting its risks and incorporating acknowledgement of them into formal budgets and other legislated actions, the agency is sharing the acceptance of those risk with the larger body politic. An example is noting the risks caused by minimal funding for bridge and pavement maintenance. The low funding levels create risks of declining asset conditions. If the agency acknowledges those risks in its budget, adoption of the budget by the legislature and governor spreads the risks among the entire government.

1A: Assign Strategic Risks to the Director or Commission

The policy should note that strategic risks are ones that can affect the goals and objectives of the organization. If these risks are not managed, they can thwart the agency's overarching objectives and ripple through other programs, projects, and activities. An example of a strategic risk is the underfunding of maintenance or the agency's failure to deliver a program of new-capacity projects.

The director or commission can build understanding for risk management by citing in the policy its strategic benefits. Most obviously, mitigating strategic risks helps the agency achieve its broad goals and supports achievement of program, project, and activity objectives. By accepting responsibility for the strategic risks, the leadership demonstrates its commitment to risk management. The active engagement of leadership in identifying and managing strategic risks sends a strong signal of support throughout the organization. Leadership's buy-in and practice of risk management also provides examples to external stakeholders that the agency is actively managing its major strategic risks.

1B: Incorporate Strategic Risks into Key Policy Documents

The leadership also can demonstrate its commitment to risk management in several practical ways. The senior leadership or commission can include a discussion of risks in the agency budget. The budget is more than a list of funding categories. It can be an important policy document that actively engages the executive and legislative branches. Because of the complex environment and multiple stakeholders affecting transportation agencies, the program objectives set in the budget face a host of already-discussed risks. Agency leaders can use the budget document and testimony to illustrate the risks facing the agency's strategic objectives and how it intends to manage them.

Many agencies also have business plans, work plans, or other short-term operational plans[42,43,44] that are more detailed than budgets and spell out the specific initiatives they intend to pursue in the year or biennium. Such plans generally list the agency's annual priorities, and they often list program priorities and identify specific projects to be delivered. A common strategy for integrating risk management into agency practice is to include a

discussion of risks in these key agency documents. The documents both address critical strategic priorities and present high-profile opportunities for the practice of strategic risk management.

Perhaps the most effective application of strategic risk management by agency executives is their embrace of it in regular management meetings with staff and the assignment of risks to specific executives. Most agencies have periodic performance-reporting and policy-review meetings. These may occur with the agency's commission or internally with senior staff. Generally, in such meetings performance reports are reviewed and progress and problems are discussed. Incorporating the discussion of strategic risks in these sessions can create high-level focus on managing risks and send a strong signal to staff that risk management is an essential practice.

Senior leaders can use a risk map similar to the one shown in Figure 6 as an icon to illustrate the highest risks they will focus on. The risk map can be used in reports to the commission and staff, budget, STIP, and other agency reports to stress that leadership will emphasize control of these risks.

Risk maps such as Figure 6 allow at-a-glance identification of which risks the risk owner is

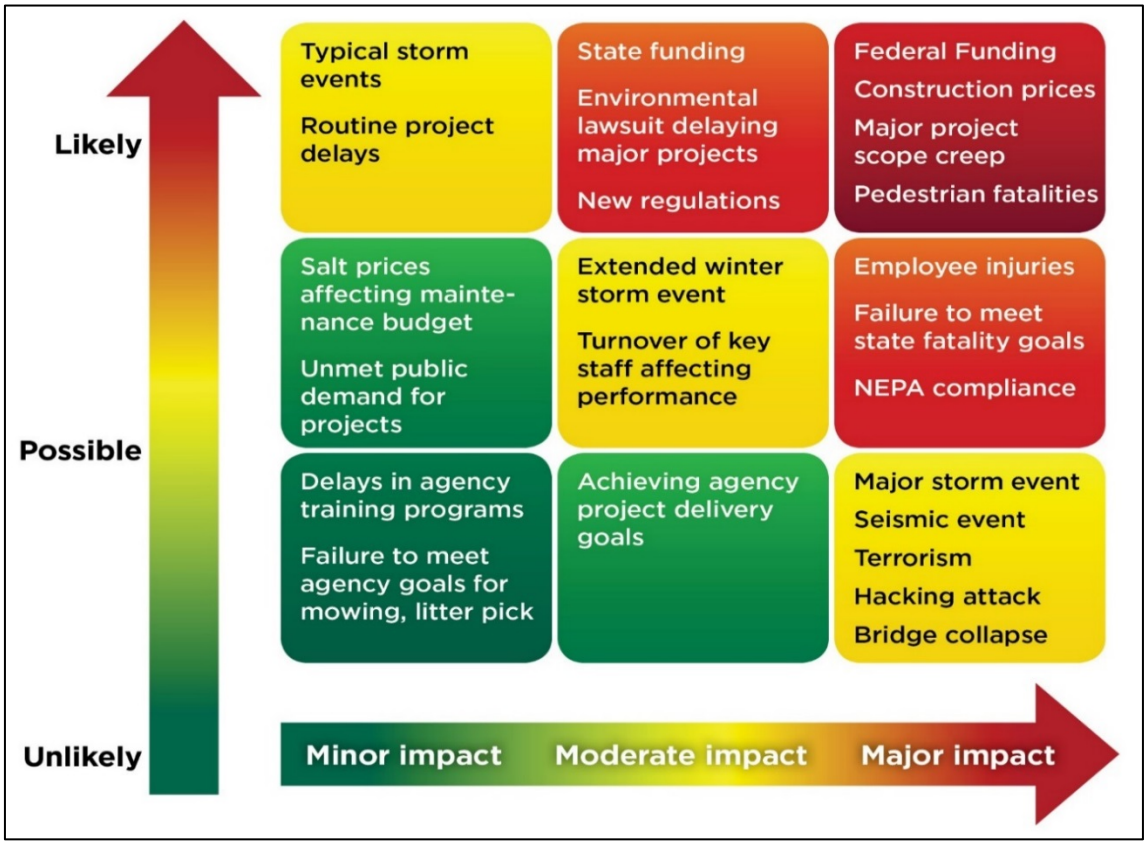


Figure 6 An example of a risk map.

managing most closely. In this case, monitoring the uncertain federal funding process, tracking construction prices, and addressing an increase in pedestrian fatalities are the strategic risks the director or commission owns. These risks are estimated to have significant

impact on agency objectives and to be likely to occur. Although potentially serious, risk episodes such as a major storm event, seismic event, terrorism, or bridge collapse are unlikely to occur in the near term. The agency develops contingency plans for these risks, but does not expect to do more than monitor them and keep contingency plans in place. The chapter on treating risks provides detail on how risk treatments are addressed.

For the senior leaders who own these strategic risks, the coloring represents the degree to which they will continually focus on these risks.

1C: Assign Program Risks to Program Owners

The next level of risks are program risks. As Chapter 1 states, programs are a group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually. The agency's risk policy should define programs and cite which programs it recognizes in the organization. It also should identify the program risk owners by position.

The duties and responsibilities of program owners to manage risks can be enumerated. These duties would likely include the following:

- Apply the ISO framework to their major program objectives and activities:
    - Identify risks to their program.
    - Analyze those risks.
    - Evaluate the risks.
    - Manage the risks.
    - Monitor and communicate effectively about the risks to other stakeholders.
- Ensure staff is adequately trained in risk management.
- Maintain effective controls over risks and document risk activities.
- Communicate effectively to senior managers and peers if risks exceed the risk appetite and threaten to impact program objectives.

1D: Assign Project Risks to Project Managers

In the risk policy, a relatively large number of project managers should be identified by position and the expectations for them enumerated. In many agencies, a project risk management process already exists. The agency enterprise risk policy can indicate how the application of risk management is scaled to the size, cost, or complexity of the projects being managed. Routine culvert replacements or resurfacings may have few risks and require simplified risk management efforts. Complex or expensive projects may have formal risk management plans that involve comprehensive consultation with all stakeholders to identify, measure, mitigate, and monitor risks to cost, scope, schedule, quality, and project impacts on neighborhoods, the environment, and traffic.

The section on developing a risk register provides detail on managing project risks. The policy could merely note that each project above a certain level of cost or complexity requires a risk management plan and risk register.

1E: Assign Activity Risks to Activity Leaders

Many activities occur in a transportation department. When they are successful they provide essential information or services that support projects, programs, and strategic objectives. When they break down, their effects can ripple through the organization and spill over into reduced service to the public. The following are the types of activities that are assumed to be addressed:

- Snow and ice control
- Traffic control device maintenance
- Incident response
- Drainage maintenance
- Counting traffic
- Providing network and telephone services
- Conducting modeling for pavements, bridges, and maintenance elements
- Vehicle maintenance

All of these types of activities are routine, but a breakdown in them can lead to significant problems for the public and the organization. Even a localized breakdown in a function such as vehicle repair can have a major impact on snow and ice control in the winter. The policy could note that all activity managers should develop a risk register and risk management plan for their activities and report to higher levels of management the risks that could impede the achievement of these activities to the identified standard of performance. Periodically, perhaps on a quarterly basis, the risk register is reviewed and updated if circumstances warrant.

For example, snow and ice control managers often acquire equipment and purchase salt during the summer. Delays in equipment repairs or purchase or spikes in salt prices or availability in the summer hold obvious potential risks for winter operations. Similarly, if traffic crews experience retirements or illness in signal crews, the routine preventive maintenance and inspection of traffic control devices could lag below acceptable protocols. These risks could be reported and managed. An increase in breakdowns in roadway loops and traffic cameras can presage a reduction in the quality of incident response. Increasing downtime in the computing network can create inefficiencies across the department. Each of these performance issues creates risks that the activity owners can be expected to manage. Table 1 illustrates the levels and types of risk to be addressed in the policy. It provides a list of the risk owners and summarizes the types of risks they are expected to manage.

1F: Set the Risk Appetite

The agency director or commission articulates the risk appetite, or at least the reference to how the many levels of risk appetite will be set. The risk appetite is the tolerance for risk the agency is willing to accept. It will vary by activity and risk type. Some expressions of risk appetite can be qualitative, such as the agency has a very low tolerance or threshold of acceptance of risk to ethical behavior, theft, or obvious threats to public safety. Other risk appetites can be quantitative, such as an agency wants 90 percent of its pavement over a 10-year period to be in fair or better condition. Agencies with a good understanding of risk and their risk appetite use them to make cross-program tradeoffs and to balance short-term and long-term needs. The risk appetite serves several purposes:

Clarity: It provides guidance to employees on what risks they should be willing to take and

which they should avoid.

Table 1 Risk types and their owners.

Risk Levels	Owners	Types of risks
Strategic Risks	CEO Senior staff Board or commission	Financial risks to agency income Operational risks caused by lack of staffing, training, or poor performance External risks caused by political or social issues Overall preparedness for disaster response Information risks that create department-wide impacts, such as outdated management systems Major regulatory or legal compliance risks
Program Risks	Leaders of major programs, such as safety, pavement, bridge, maintenance, information technology, project delivery, human resources	Performance risks caused by lack of training, execution, or resources to deliver the program Information risks caused by poor data in the program or inadequate analysis Financial risks caused by increasing prices Stakeholder risks caused by contractors or vendors essential to the programs Major project risks if they exceed the level at which they can affect an entire program
Project Risks	Project managers	Risks to the cost, scope, schedule, or quality Project impacts on neighborhoods and environmental compliance
Activity Risks	Activity managers	Performance risks caused by lack of training, equipment, or execution Cost increases impinging on activity performance Risks to execution caused by outside events, such as extreme weather

Value: The risk appetite allows decision makers to better understand how to make investment tradeoffs related to risks. If the agency has little tolerance for noncompliance with environmental regulation, the decision maker may increase spending to avoid that risk. Conversely, if the agency has a high risk appetite for uncut grass, the program owners will not take risks to get the grass mowed. The risk appetite provides general guidance on the worth
of risk-avoidance strategies

Encouraging risk taking: The risk appetite seldom will be zero. If the appetite were zero, the decision maker would never take a risk and would spend inordinately to avoid any risk. With a stated risk appetite, experimentation can be encouraged.

Complementing performance management: Because risk management enables sound performance, the risk appetite provides direction to decision makers who are trying to achieve performance targets.

Based on the risk appetite for each target, they will know how much extra effort or expense is justified to achieve the target. Agencies with mature performance management have learned that when unexpected events occur, it may be too expensive to achieve a target in a given year. In years when floods occur, road condition targets may not be met. The risk appetite indicates how much variance in performance is acceptable.

There probably will be too many levels of risk appetite for each to be addressed specifically in the policy. The policy can include general direction, but instruct each risk owner to suggest and have approved a risk appetite. The various risk appetites can be included in each risk register and risk management plan.

These components of a risk management policy are combined in the following sample policy. It is intentionally brief and is expected to be complemented by a more-detailed risk management handbook or guide for agency personnel.

A Sample Risk Management Policy

It is the policy of this department to manage the risks to our strategic objectives, programs, projects, activities, and, most important, the public. We will identify and manage our risks:

- To reduce the chance of harm to the public and the public's interests
- To allow us to improve decision making by weighing risks with potential rewards
- To encourage rational risk taking when it can result in benefits to the public
- To increase value by reducing spending on low-risk activities and increasing investments to reduce major risks
- To provide clarity and transparency in our decision making so the public better understands the risks we face
- To support achievement of our objectives and performance targets

All employees are expected to understand what risks are and how we manage them. Every employee shall understand their role in managing risks at every level. We will assign and manage risks at the following levels:

Strategic risks are those that could affect the entire department and help or hinder the achievement of its major priorities. These risks will be managed by the director, senior staff, and commission.

Program risks are those that could affect performance of our major programs, including safety, pavements, bridge, maintenance, information technology, local programs, project delivery, finance, and human resources. These risks are the responsibility of the program managers.

Project risks are those that could affect the cost, scope, schedule, quality, and impact of construction projects. These risks are assigned to project managers in the programs of new construction, pavements, bridges, safety, roadway, local projects, and maintenance.

Activity risks are those that could affect major ongoing activities, such as snow and ice control, incident response, maintenance of traffic control devices, communication network operations, equipment maintenance, and data collection.

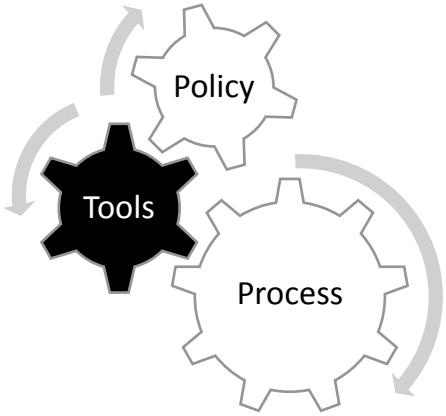
Each risk owner shall develop a risk register in accordance with our Risk Manual. It shall be reviewed at least quarterly and needed changes noted. It is the responsibility of risk owners to report upward to senior management and laterally to peers if risks to his or her area could affect other objectives, programs, projects or activities. Communication shall be continuous and effective.

All risk owners are expected to update their risk registers and provide them to the department's risk center, according to the Risk Manual. The risks shall be shared with staff, and each risk manager is expected to keep his or her staff informed of their role in managing the risks in their area.

Step 2: Provide the Tools for Managing Risks

Most guides indicate that the following tools and functions are needed for an agency to manage risks successfully:

- Risk management unit or subject matter expert
- Training program
- Ongoing support and problem solving
- Guide or manual
- Website or other repository for posting risk registers and serving as an information clearinghouse
- A process to communicate vertically and horizontally throughout the agency.



2A: Appoint a Chief Risk Officer or Create a Risk Unit

The director or commission often appoints a chief risk officer or risk-management subject-matter expert or creates a risk unit. This person or unit is charged with tasks such as developing training, developing a manual, providing risk tools, and coordinating risk processes. This person or unit can play many roles, such as subject-matter expert, advocate, troubleshooter, and liaison.

Modern management structures often have this person report to the chief executive officer or a high-ranking executive. Some authors note that the risk manager's role has grown substantially in recent years. One analogy is that risk managers have moved from minor backseat passengers to those who help drive the car.[45] In past decades, the risk manager was a technician or mathematician who helped develop probabilities and control insurance costs. In the modern corporate environment, the risk manager is one of the chief enablers in an organization. She or he helps the organization identify, monitor, and mitigate its major risks. The chief risk officer also supports the cycle of risk management processes. These ongoing events are described in the risk management process.

2B: Provide Staff Training

Because risk management is new, it is likely that the risk manager will institute training for staff to understand and learn how to manage their risks. Implementing a risk management culture requires a substantial change management effort. Training plays a key role in this change management. Training in risk management is available through the National Highway Institute (NHI) and other public and private-sector providers.

2C: Develop a Risk Manual or Guide

The risk manager should consider developing an agency risk management guide or handbook. This could detail how the organization chooses to apply the general risk management framework to its unique environment. The guide can address elements specific to the agency, including the following.

- how it wants the risk management process to interface with other key cycles, such

as development of the STIP and long-range plan
- reporting formats and cycles
- who are the risks owners?
- how each owner should develop a risk appetite or tolerance?
- how units should communicate with each other and with other levels about changes in their risk profile that could affect other areas
- what training and performance levels are expected?

2D: Create Risk Tables and Registers

Among the most important tools the risk manager can provide the staff are risk registers and risk consequence tables or scales as seen in Figure 7. These generally are simple tools, but they are used almost universally to document the consequences and likelihood of risks and to note what treatment options are to be taken.

Although these tools and how to use them are explained in greater detail in Chapters 5 through 8, they are discussed here to illustrate how they are necessary to establish a risk process. In the ISO and other risk frameworks, risks are considered from two complementary perspectives: What is their potential consequence and what is their likelihood? Risks

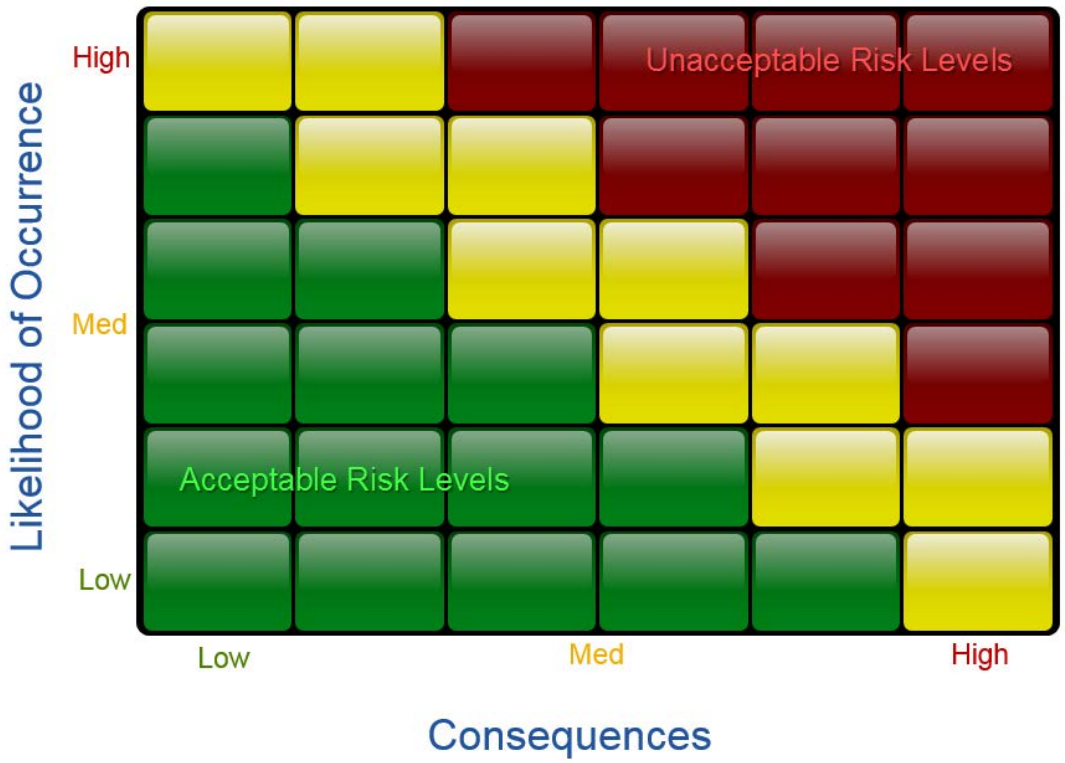


Figure 7. A risk map color coded by importance of risks.

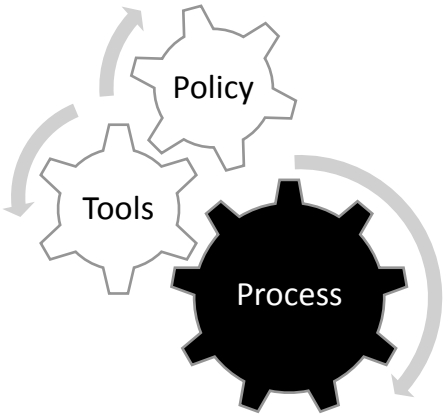
with
low consequence and low likelihood may warrant monitoring and routine risk treatments, but may not need extensive treatment. Conversely, risks with high consequence and high likelihood rise to the top of the risk-treatment priorities. Figure 8 includes a stylized repre-

sentation of a risk map in which the consequences and likelihood of risks can be evaluated and plotted. These can be ordinal scales of high, medium, or low, or they can be interval scales such as a perceived likelihood of once a year, once a decade, or once a century.

The risk register usually is a spreadsheet-like summary of the risks and their various attributes, including how the risk manager expects to treat them. They are discussed in more detail in Chapter 8. Risk registers occur at multiple levels. A risk register for strategic risks is fed by risk registers at the program, project, and activity levels. Risk registers often include color-coded scales to indicate the rank ordering of risks, similar to heat maps. Risk registers serve several functions. They document what risks have been considered, the relative consequence and likelihood of the risks and how the risks may spill over into other program areas. They also summarize the treatment. As part of the training and process, the risk manager should provide a standard risk register and risk-evaluation tables so that risks are measured consistently across the organization.

2E: Create a Risk Website or Other Reporting Mechanism

The active use of the risk management process—or the active managing of risks—is critical. The agency leader will probably want to instruct the risk manager to create a risk management website or other repository for risk registers, risk plans, and related materials. The rapidly changing nature of risks reduces the effectiveness of static paper reports and increases the effectiveness of real-time websites and updates. A website can house the risk registers, manuals, and supporting materials in a repository. They also can serve a news and information function by sharing updates to risk profiles, advice on training opportunities, and other items of interest on managing risks.



Step 3: Integrate Risks into Key Agency Processes

While creating the risk management program, the director or commission should identify the processes the agency will use to actively manage risks. Preferably, these processes will be linked to every step of the agency's long-range planning, programming, budgeting, and performance management steps. Also, they should be continuous and work in parallel with the annual cycles to identify and execute performance objectives.

3A: Begin the Cycle: Set the Priorities and Agency Context

Risk management should focus on enabling agency objectives. It should not be a standalone requirement unrelated to the priorities of the organization. The first step in the process of integrating risk management into key agency functions is for the director or commission to reemphasize agency priorities and the risks and opportunities surrounding them.

It is helpful to precede this step with a strategic and environmental overview from the senior leadership. This could take the form of an analysis of strengths, weaknesses, opportunities, and threats or a simple report from the leadership. Either would result in an annual or periodic statement of the following:

- Any changes in the agency's strategic objectives since the last publication
- Updates on the legislative or budget environment that may influence agency priorities for the upcoming period
- Acknowledgement of changes in the external environment that may affect the agency's objectives or risks, such as changes in public sentiment, shifts in the economy, new legal requirements, and agency opportunities and obligations
- Changes in agency policy that need to be incorporated into the risk process

To integrate this step deeply into the agency process, it may be useful for the director or commission to link this cycle with the annual budgeting or STIP update process. The point is to not divorce the risk cycle from other normal business cycles. The intent is to integrate them.

It also could be helpful for the director or commission to accompany this overview with a summary of highlights of the past year's performance and management of risks. What risks were well managed? What risks created issues? Which risks have faded and which have risen in prominence since the last update? Because risk management enables performance management, a summary of how the agency performed in achieving its objectives provides a basis for updating risk registers at all levels of the organization.

This overview also could include any changes in agency targets or objectives. If units are managing risks to performance objectives, their starting point is to clearly understand the performance they are attempting to achieve. A key early step in the risk-management process is for agency leadership to clarify performance objectives.

3B: Populate the Risk Registers

The next step is for the risk owners to populate their risk registers using the five steps enumerated in the ISO process: establish the context, identify risks, analyze risks, evaluate risks, and manage risks. This step would logically be done in parallel with reviewing and updating the program, project, or activity performance management plan or program for the year. The risk manager would review his or her area's performance during the past year or business cycle, evaluate the strengths and weaknesses of the performance, and identify the performance objectives for the upcoming year or cycle. Once those are clarified, the five-step risk analysis determines if the risk register or risk management plan for the performance area should be updated. The agency's risk process can direct risk owners to extract from the risk registers simple risk management reports for each risk, such as Figure 8. It is a sample update for managing risks to the objective of delivering projects on time. This update provides a summary of how the project-delivery team is proceeding with its efforts to manage the risks that prevented it from achieving its performance target.

To further integrate the risk management process into the organization, these types of risk reports can be incorporated in the annual performance plans for individual staff, included

in department business plans, or stated as objectives at the divisional level. Clearly communicating and sharing these identified risks to the project-delivery process informs everyone in the department with a role in reducing the risks to project development.

Performance Objective: On-time project delivery to achieve the objectives of the Long-Range Plan, Transportation Improvement Plan, Asset Management Plan, and Highway Safety Plan			
Target	90% of project development milestones achieved within 30 days of schedule		
2014 Performance	↓ 79% achievement of project-development milestones		
Performance Issues	Inability to clear utilities from rights of way Slow reviews in specialty areas, such as drainage and lighting Inability to secure environmental permits on time		
2015 Risks	**Utility Clearance**	**Specialty Reviews**	**Permitting**
Risk Severity	**High**	**Moderate**	**Moderate**
Strategy to Manage the Risks	1. Earlier coordination with utility companies 2. Augmenting staff with consultant assistance 3. Partnering with utilities 4.Training of project-development staff	1. Improved coordination with specialty reviews to achieve on-time reviews 2. Increased use of consultant reviewers	1. Partnering with resource agencies 2. Training with design consultants to anticipate permit needs 3. Improved scheduling of permit requests

Figure 8. A sample risk update report.

3C: Identify the Communication and Monitoring Function

The director or commission needs to instruct the risk manager to identify methods of two-way communication so the leadership can monitor the treatment of risks and the risk manager can alert leadership to changes in the risk environment. Most risk guides recommend formal and continuous communication channels to enable active, ongoing, hands-on management of risks as they arise.

On at least a quarterly basis, risk owners should review risk registers and convey changes in the risk profile through the following:

- Executive staff meetings in which progress toward the annual performance measures is reviewed and effectiveness of risk treatments is evaluated
- Ongoing reports to agency dashboards and the risk website on risk-mitigation efforts and results.

3D: Refresh with an Annual Update

The cycle is completed each year with evaluation of agency performance for the past year and identification of changes in agency objectives, targets, or risks for the upcoming year. These objectives, targets, and risks are cascaded into the agency's priorities and risk efforts at the strategic, program, project, and agency levels. The cascading or linkage occurs by incorporating the risks into key agency documents and processes, such as the budget, employee work plans and evaluations, unit work plans, and STIP.

At the annual update, the director and risk manager should consider whether any strategic-level risks have moderated so they can be downgraded to program, project, or agency risks. Conversely, have any risks from other levels become so severe that they are elevated to strategic risks to be managed by the executive staff? An example is a new statewide payment system that poses a risk in its first year if it has the potential to disrupt business operations while it is deployed and debugged. As the system becomes routine, the agency downgrades it to an activity risk and it is treated by the billing staff. If an environmental agency threatens action because construction practices are violating storm runoff regulations, that risk is elevated from the activity to the strategic level because such a risk could threaten the success of the entire construction program. Conversely, it can be an opportunity to improve environmental practices. The importance of risks should rise and fall naturally over time as new issues arise and old risks are successfully managed.

Figure 9 illustrates the nature of the risk-management cycle. While the director reports strategic risks from the top down, risks at the program, project, and activity levels are regularly reviewed and updated to the agency-wide reporting system. This allows risks to be reported upward for adjustment to the performance plan and risk register.

The policy, tools, and processes create an ongoing, continuously reinforcing framework intended to ingrain the managing of risks into the organization. Close linkage of risk management to other key business cycles can reduce the chance that risk management will be become an ancillary task unrelated to the priorities of the department and its staff.

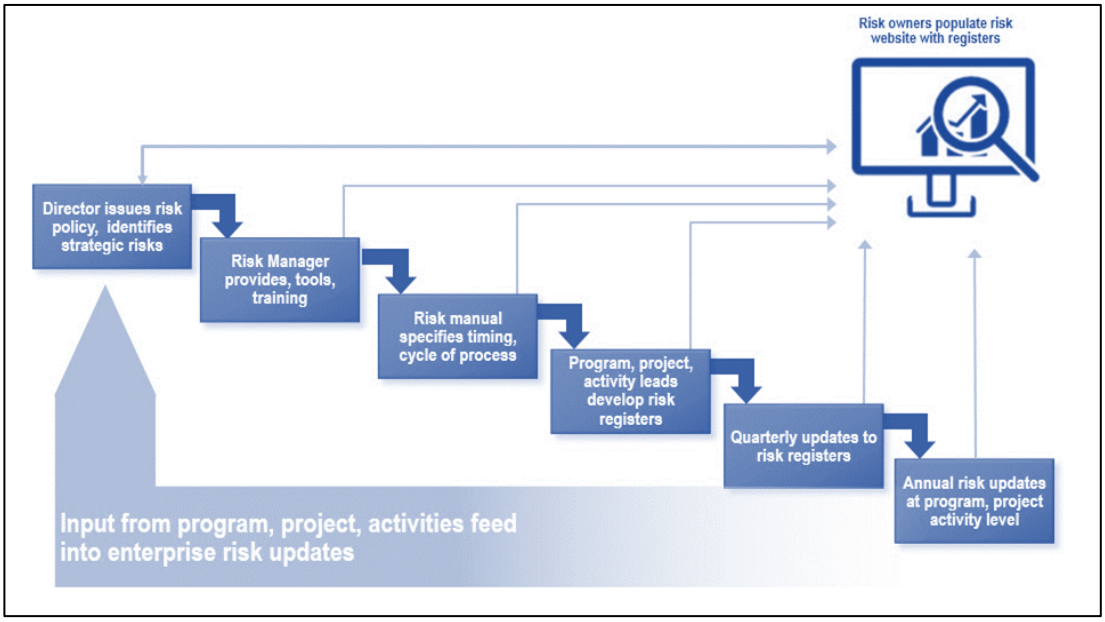


Figure 9. Risk management flows through the organization, cascading from strategic risks to programs, projects, and activities. The risk manager, manual, training, tools, and website are key enablers in the process.

Summarizing the Tasks and Responsibilities

Table 2 is a RACI matrix that summarizes who is responsible for, accountable for, consulted on, and informed of tasks. The RACI matrix is a punch list for an executive to implement an enterprise risk management program as described in this chapter. It summarizes the key steps and to whom the director or commission should assign responsibility and accountability, as well as who is consulted and informed.

Table 2 A matrix of responsibility, accountability, consultation, and who is informed of the steps needed to implement an enterprise risk management program.

Responsibility for ERM

Key	
R:	Does the step
A:	Accountable for the step
C:	Consulted with before the step
I:	Informed when the step is completed

Activity Adopt ERM Policy

PROCEDURE	Draft, Distribute, Adopt ERM Policy
DEPARTMENT	Director

STEP	DESCRIPTION	Director	Commission	Senior Staff	Mid-Level Staff	Front-Line Managers	
1	Inform Commission, senior staff of intent to adopt ERM	R, A	C	C	C/I	I	
2	Receive senior staff input	R,A	C	C	C, I	C, I	
3	Draft ERM policy	R,A	I	I	I	I	
4	Circulate ERM policy and obtain feedback	R,A	C	C	C	C	
5	Adopt ERM policy	R, A	A	I	I	I	

Activity Appoint ERM Coordinator

PROCEDURE	Assign staff responsibility for ERM process
DEPARTMENT	Director

STEP	DESCRIPTION	Director	Commission	Senior Staff	Mid-Level Staff	Front-Line Managers	
1	Appoint ERM coordinator or Risk Manager	R,A	A	I	I	I	

Activity Develop Risk Tools, Process

PROCEDURE	Provide staff risk tools, identify risk processes
DEPARTMENT	Risk Coordinator or Risk Manager

STEP	DESCRIPTION	Director	Commission	Risk Manager	Senior Staff	Mid-Level Staff	Front-Line Managers
1	Develop likelihood and impact scales	C	C	R,A	C	C	C
2	Develop risk register format	C	C	R,A	C	C	C
3	Train staff on initial use of scales, register	C,I	C,I	R,A	C	C	C
4	Acquire customer requirements for ERM process	C	C	R,A	C	C	C
5	Draft ERM manual based on customer requirements	C	C	R,A	C	C	C
6	Adopt ERM manual	R,A	A	C	I	I	I
7	Develop initial risk registers for Programs, Projects, Activities	R,A	R,A	R,A	R,A	R,A	R,A
8	Populate agency-wide Enterprise Risk Register	A	A	R,A	C	C	C
9	Incorporate risks in agency objectives, work plans, tasks	R,A	R,A	R,A	R,A	R,A	R,A
10	Update risk registers per agency schedule	R	R	R,A	R	R	R
11	Communicate risks to external partners	R	R	R,A	I	I	I
12	Monitor risks for updating risks at all levels	A	A	R,A	A	A	A

Establish Escalation and Trickle-down Protocols

One of the important aspects of risk management is to have the right person manage the risk at the right level at the right time. To ensure timely management of risks, an organization should establish and communicate clearly the protocols for how risks will be handled

and communicated up and down the organization.

Some risks that are occurring at lower levels of the agency may have wider impacts and may also impact higher level objectives and activities. Hence, effective management of risks may require that some risks be escalated from the bottom levels up the chain of command appropriately. It will require the establishment of protocols that make it clear to all levels of agency personnel when to escalate the communication of a risk up to the next level. In this bottom-up process of risk escalation, clear direction should be given on who should address the risk and at what point it should be escalated to the next level. This will ensure that risks from lower levels that bubble up through the organization will get addressed at the appropriate level before requiring action from the senior leadership. The escalation protocol will also ensure that risks are managed at all levels and are not escalated to higher levels unnecessarily. An important benefit of having such protocols is that risks identified as lower level risks are managed appropriately and will not pose risks to program and agency objectives.

Similar to such a bottom-up escalation approach, clear protocols should also be established for top-down communication. This will provide direction on when and who will communicate a risk down the chain when the risks identified at higher levels trickle down and impact the objectives and activities at lower levels in the organization.

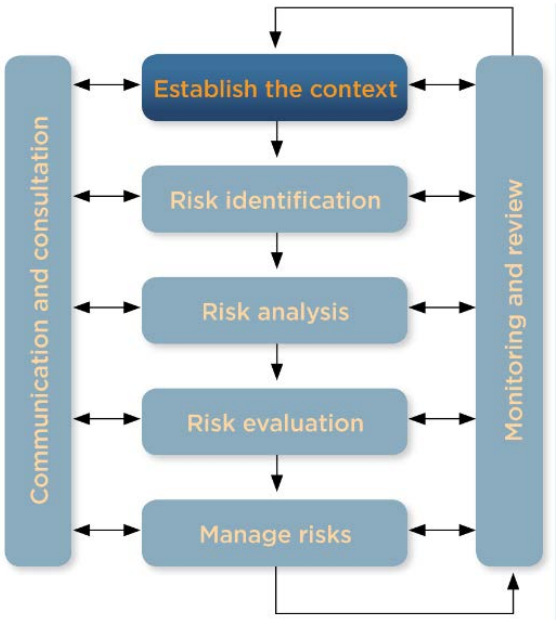
Escalation and trickle-down protocols will ensure that responsibility for managing risk is assigned at the right levels in an organization and concerns about risks are methodically handled before they impact other levels in an organization.

Chapter 3: Establishing the Risk Context

Summary

This guide now shifts to addressing the detailed tasks needed to conduct risk assessments. Chapters 3 to 8 are intended for the practitioner who will lead a risk-assessment workshop or a work unit's risk effort. These chapters provide step-by-step guidance that is scalable to conducting risk assessment at the strategic, program, project, or activity level.

This chapter explains the first step in the process, which is establishing the context or environment surrounding the risk. This step reviews the objectives and the environment in which they exist. Four program areas are used as examples: highway safety, pavement, local project oversight, and intelligent transportation system (ITS) programs.



Identifying Risk Focus Areas and Risk Owners

With the risk policy, tools, and process in place, the organization can begin to assess risks. The agency enterprise risk manager or risk subject matter expert can work with individual work units to help them with the risk assessment process. Until the agency has completed several years of risk assessment, it is recommended that the risk manager work closely with units to assist them with their risk assessments.

Assigning Risks and Forming Teams to Assess Them

In this step, the director, risk manager, or other delegated leader appoints as "risk owners" the leaders of programs, projects, and activities. Senior leadership retains the strategic risks as its own.

As the risk owners begin their risk management efforts, they should appoint knowledgeable teams of people who are familiar with the subject area and represent a range of perspectives and duties. Because risks can come in many forms, having different perspectives on these teams can help them identify the full range of possible issues. The number of groups formed and who is in each can vary, but generally the groups should be broad enough to capture essential perspectives without being so large that they are unwieldy. Groups of eight to 12 people are optimal. Adding outside stakeholders to the risk team can be advisable if the group's objectives can be influenced by external events. The outside members can provide important perspectives.

The complexity and formality of the identification of objective and context depend on the complexity and scope of the objective. If a board or commission is to undertake a formal risk assessment of its strategic objectives the first time, this effort may extend over weeks. The group may engage a facilitator, formally document each phase, and conclude with formal adoption of the risk assessment. At the other end of the continuum, an activity owner may assemble staff members and outside stakeholders and conduct the assessment in an afternoon. The extent and formality depends upon the scale of the objective.

The risk assessment process should be an open, participatory one that encourages solicitation of a wide range of perspectives. Some authors note that broadening the circle of participants will bring out observations that may not be apparent to the process owners who work with an issue every day. Some authors also suggest that an opportunity for anonymous input be provided. Sometimes risks are created by internal performance or processes that staff may be uncomfortable raising in open sessions. The overall approach to the risk assessment process should be participatory, far-reaching, and candid.

Once formed, the team begins its risks assessment through one long or a series of shorter meetings or workshops. Preferably, these are led by a facilitator or leader who keeps the team focused on its objectives, schedule, and product. The risk meeting or workshop process should balance having enough structure for members to progress steadily while accommodating wide-ranging discussion to identify risks from many perspectives.

Clarifying the Objectives and Their Environment

All the government guides reviewed for this report include the same starting point for risk assessment: clarify the objective and place it in the proper context. Many call this step "identifying the context," but it also involves concurrent identification of the objective, program, project, or activity to be achieved. Some of the proprietary private-sector risk frameworks call this phase by a different name, but their frameworks begin with a similar approach. They all start by grounding the assessment in the objectives to be achieved and what internal organizational issues and external environmental ones could create risks or opportunities.

Setting the Context around the Objective

The risk-assessment process and workshop should begin with clear documentation of what is to be achieved by the objective. At the strategic levels, objectives may be broad, such as ensuring the agency is well prepared to address storm events and other catastrophes. Or the objectives could be specific, such as ensuring that a program of high-profile projects is delivered on time. Regardless, clarity in performance should be defined because that will

have a major bearing on the level of effort devoted to managing the risks. If an agency routinely achieves a given objective, risk-management activities can focus on monitoring to ensure continued good performance. If performance has lagged far below the target, the context-setting exercise can document the performance gap to be closed and probably identify several major environmental factors that affect the performance.

Second, the group should determine the risk tolerance or appetite for this objective. Sometimes, the risk appetite is set in an agency policy, design standard, or other procedure. If the agency has low tolerance for failing to achieve the objective, that should be understood and considered an important factor in the environment surrounding this objective. An example is the risk appetite for missing stop signs compared to that for uncut grass. In a risk workshop for highway maintenance priorities, it could be noted that the tolerance for missing signs is much less than the tolerance for uncut grass. Later in the process when risks are being managed, the risk appetite contributes to decisions on how to prioritize risk-management efforts.

Third, the linkage of this objective to other objectives should be considered. It should be noted if the objective is part of a larger endeavor or is a supporting activity to a larger initiative. The relationship of this initiative to others may have a bearing on later risk-identification and evaluation considerations.

Fourth, the possibly lengthy list of external factors that influence the objective should be noted. Elements to consider include the following:

- The limits and authority of the organization relative to the objective. Does the owner of the objective or program have broad discretion or limited authority? Is legal responsibility for this objective shared by other entities, or are they limited to this organization? With whom is responsibility shared? What statutory or regulatory requirements are associated with this objective?
- Does controversy surround this objective and, if so, what issues does it create?
- What social or cultural considerations surround this objective? If an objective intersects with other social objectives, such as achieving environmental justice or creating livable communities, those issues should be noted.
- Directives from higher authorities, such as the governor, or other agencies should be considered as part of the context.
- Do technical or budgeting constraints affect the objective and options surrounding it?
- What time horizon is involved?

Fifth, the internal environmental should be documented:

- What internal policies or procedures influence the objective?
- What data or information is available and to what extent is it adequate?
- What organizational culture issues influence the objective?
- What are the lines of authority and responsibility?
- What are the agency's capability and competencies related to the objective, program, or activity?
- What organizational direction exist, such as timelines and budgets?

Figure 10 captures some of the many elements in the environment surrounding an objec-

tive. The influences in the context are shown as being in motion, which reflects their dynamic and fluid state. Throughout the year or life of a program, the degree of influence

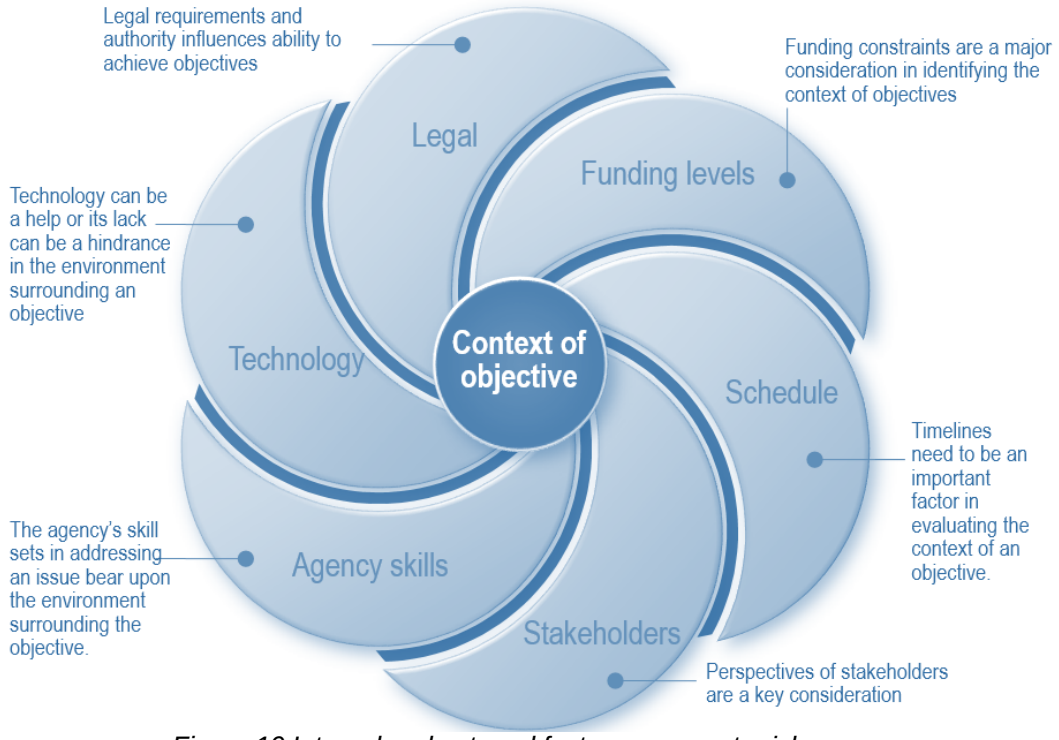


Figure 10 Internal and external factors can create risks.

created by any one of these factors is likely to rise and fall as both internal and external environments change. The point of the context-setting phase is to develop a clear acknowledgement of the context surrounding the objective so that in later stages participants can make informed decisions about the causes of risks and how to manage them.

The British Treasury's guide on risk management stresses the changing and nonlinear context surrounding objectives.[46] It notes that the risk management process will require a continual balancing of a number of changing influences from the internal and external environment. Also, risks cannot be viewed in isolation, but often must be considered linked to other risks and elements in the larger context of society.

A final consideration should be trend lines of performance or trends in the external environment. Has performance in this objective been steadily rising or falling? Are external factors playing a greater or lesser role on this objective than in the past? An understanding of how the context and objective have changed over time may provide insights on future influences on the objective and the risks it may face.

Examples of Applying the Risk Management Process

Chapter 8 elaborates on the risk management process by illustrating how it can be applied

to seven typical transportation agency programs:

- Asset management
- Safety
- External risks, such as floods or seismic events
- Financial risks
- Information risk
- Business risks, or risks to operations such as purchasing and payroll
- Project and program, or risks to a related collection of construction projects such as those in a bridge or pavement program

This section illustrates how the context-and-objective identification stage can be applied to four strategic objectives: developing an asset management plan, achieving highway safety objectives, local project oversight, and ITS.

Tools for the Context-Setting Exercise

The context-setting exercises begin with the asset management, safety, local project oversight, and ITS teams assembling with facilitators or organizers, who review the objectives for the session. This ensures the teams understand the risk exercise and will participate in identifying the internal and external context issues and stakeholders they need to understand to identify and manage risks to the objectives.

For this theoretical exercise, the asset management objectives are the following:

1. Produce a transportation asset management plan meeting the MAP-21 requirements by June 30, 2016.
2. Develop a program of projects and maintenance activities to achieve and sustain targeted asset conditions over the next decade.
3. Develop adequate asset inventories and asset forecasting capabilities to support asset management objectives.

For the safety team, the objectives are the following:

1. Progress to Target Zero by reducing fatalities and serious injuries by 20 percent over the next decade compared to 2014 levels.
2. Reverse the trend of increasing crashes involving vulnerable populations, including pedestrians, bicyclists, the elderly, and motorcyclists.
3. Deliver on time and on budget the Safer Streets program of systemic and targeted countermeasures to reduce crashes.

For the project oversight team, the objectives are the following:

1. Assist local governments with achieving their project-delivery objectives.
2. Ensure effective federal and state oversight.

For the ITS team, the objectives are the following:

1. Improve travel-time reliability through effective operation of ITS.
2. Regularly update ITS processes, technology, and decision-support tools to support evolving reliability strategies.

The teams and workshop facilitators can use one of several methods to elicit comments

from all participants:

- Brainstorming, in which the members are called on to identify issues in the environment surrounding the objective until all suggestions are exhausted
- Review of checklists by topic area, which can include the team methodically considering contextual issues relating to the legal, social, natural, cultural, financial, and regulatory environments.
- Review of other groups' analyses to identify common issues.
- Review of literature searches or other summary reports prepared for the exercise.

In this phase, no ranking of the issues is done, so more quantitative group techniques such as the Delphi method, in which participants vote on values and the scores, are not generally used. The ranking of importance and impacts occurs in later stages.

Figure 11 Internal and external factors greatly influence the risks and opportunities public agencies face.

As Figure 11 shows, public agency objectives are influenced by many internal and external factors that cannot be ignored in the risk assessment. Table 3 is a typical list of issues stakeholders are likely to identify in an asset management context-setting exercise. It shows a number of issues and stakeholders that, when viewed in their entirety, indicate that the agency approaches its asset management objective with substantial uncertainties. State and federal funds are uncertain, a larger number of outside parties such as FHWA and local governments have an influence on the agency's objectives, and the agency lacks complete information for decision making. This brainstorming session for asset management sets the initial stage by clarifying the objective, identifying the stakeholders, and illustrating the environment in which the agency will attempt to achieve its objectives.

Basis for Further Decision Making

These summaries are intentionally brief and high level. They are not intended to recreate the planning process nor to produce exhaustive reports. They serve to highlight for the risk assessment team the key issues they should consider as they proceed to the next three steps of the risk assessment process. They keep the team focused on the complexity and number of issues that could create uncertainty, variability, threats, or opportunities that

affect their objectives.

Table 3 Issues surrounding the context of asset management risks.

Asset Management Objectives and Context **1. Produce a transportation asset management plan meeting MAP-21 requirements by Dec. 31, 2016.** **2. Develop a program of projects and maintenance activities to achieve and sustain targeted asset conditions over the next decade.** **3. Develop adequate asset inventories and asset forecasting capabilities to support our asset management objectives.**	
External Context	**Internal Context**
Our agency does not fully understand the FHWA rulemaking on transportation asset management plan requirements.	Agency commitment to asset management has increased and it is now formally embraced.
Critically important Federal-Aid Highway Program amounts will be uncertain over the 10 years of our asset management forecast.	Management systems are improving, but still have not provided complete confidence in the accuracy of their forecasts.
State revenue is likely to decrease because of a decline in vehicle miles traveled and improved fuel economy standards.	The agency still has gaps in key asset inventories, such as culverts and drainage items.
Heavy truck traffic is increasing on roads because of increased fracking activity.	Key management system staff will retire within five years, creating a need for succession planning.
Multiple agencies have control over many key assets, particularly locally managed segments of the NHS.	Skepticism remains among some staff on the success of preventive maintenance treatments on which our long-term asset management plan depends.
Understanding and support for asset management is increasing among local stakeholders.	Linkages and coordination between capital programs and maintenance programs are incomplete.
The construction industry is evolving to provide important services, such as bridge	Project-selection decisions still skew toward “worst first,” but continue to im-

and pavement preservation resources.	prove.
Construction prices have been volatile at times in the past decade and their future trends are uncertain.	Data are not easily accessible to all decision makers.
Stakeholders	
External	**Internal**
Public	Districts
Cities and counties	Other programs, such as traffic and safety
Legislature	Data and management system programs
Industries dependent on transportation	Budget and programming teams
Construction industry	
FHWA, FRA, FAA	

For the safety example, the risk team has produced a summary of the context typically surrounding a highway safety program in Table 4. Tables 5 and 6 summarize project oversight and ITS context.

Table 4. Sample highway safety objective and risk context.

Highway Safety Objectives and Context	
1. Progress to Target Zero by reducing fatalities and serious injuries by 20 percent over the next decade compared to 2014 levels. **2. Reverse the trend of increasing crashes involving vulnerable populations, including pedestrians, bicyclists, the elderly, and motorcyclists.** 3. **Deliver on time and on budget our Safer Streets program of systemic and targeted countermeasures to reduce crashes.**	
External Context	**Internal Context**
Changing travel patterns are increasing the number of people walking, bicycling, and using motorcycles.	Agency commitment to safety remains high and unlikely to diminish.
The average age of the state's population will continue to increase.	Crash data are still slow to come and incomplete, particularly from small cities and rural law enforcement.
Achievement of safety goals depends on many	Coordination among capital program,

partners, including police, emergency services, education groups, and the public.	maintenance, and data-analysis teams is increasing, creating a more holistic approach to safety.
Texting while driving remains too common.	Geographic information system mapping is helping clarify crash patterns.
Impaired driving is still too frequent.	Increased safety program budgets are expected to continue.
Motorcycle use is declining, but is still higher than in past decades.	Adoption of the Safety Edge℠ and roundabouts continues to show a positive contribution to crash reduction.
Safer, smarter vehicles are expected to increase in the overall vehicle population.	Cable barrier use remains high, but it increases maintenance costs.
Overall crashes and fatalities are declining, except for those involving vulnerable populations.	Systemic safety program results appear encouraging.
Emphasis on livable communities increases acceptance of traffic calming, which can help pedestrians and bicyclists.	
Crash data are incomplete and late from many local law enforcement agencies.	
Secondary crashes caused by incidents continue to increase.	
Crash patterns excluding vulnerable populations remain constant, with lane departure and intersection crashes the most common types.	
Media focus on bicycle and pedestrian fatalities is increasing as a result of recent events.	
The legislature is unlikely to enact a helmet law.	
Stakeholders	
External	**Internal**
Public	Districts
Law enforcement	Programming

Governor's highway safety representative	Data teams
Local communities	Traffic
Media	Maintenance
Emergency responders	

Table 5. Sample project oversight objective and risk context.

Local Project Oversight Objectives and Context **1. Assist local governments with achieving their project-delivery objectives.** 2. **Ensure effective federal and state oversight.**	
External Context	**Internal Context**
Local agencies are diverse in their project-management abilities and resources.	The agency lacks adequate staff to "hold the hand" of every local project sponsor.
Many local agency staff manage Federal-Aid projects only occasionally and cannot remain well informed about changing federal requirements.	The agency has project-development training and manuals that can be resources to improve project management practices.
Local agencies struggle to afford adequate scoping and project management.	The agency has adopted an objective of improving the reliability of local project delivery to ensure full use of federal funds.
Local agency staff are expected to be responsive to community project objectives, even if they complicate the project-development process.	The agency allocates a substantial portion of its Federal-Aid funds to local projects and has strong interest in their oversight.
Local agencies want to manage construction phases to ensure contractors are responsive to neighborhood concerns.	The agency faces legal liability for any problems with the local program.
FHWA considers local project oversight a high-risk activity.	
Stakeholders	
External	**Internal**
Local cities, towns, counties, and metropolitan planning organizations	Local program office

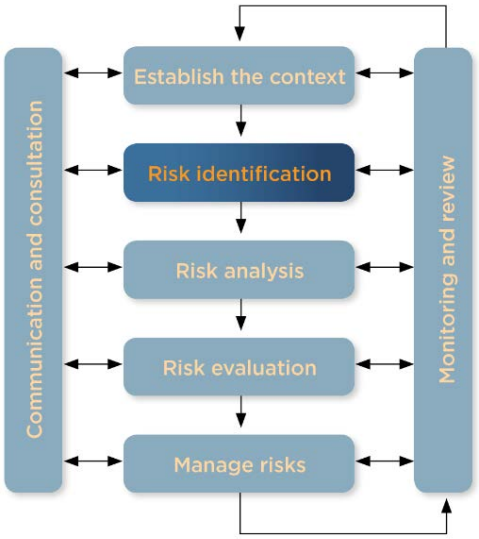
FHWA	Legal department
Resource agencies	Environmental and other review teams that must review local submittals
Local citizens affected by projects	Programming agency to manage use of federal funds
Stakeholder groups, such historic and environmental advocacy groups	Auditing office that must audit local projects

Table 6. Sample ITS objective and risk context.

ITS Program Objectives and Context **1. Improve travel-time reliability through effective operation of ITS.** 2. **Regularly update ITS processes, technology, and decision-support tools to support evolving reliability strategies.**	
External Context	**Internal Context**
Effects of incidents continue to decrease travel-time reliability.	Agency staff are unable to retain expertise for cutting-edge technology skills.
ITS system designed in the 1990s includes components nearing the end of their useful life and the agency needs to anticipate updating the system.	The agency finds it difficult to afford ITS technology upgrades.
Field equipment is subject to frequent breakdowns because of age.	The agency is unable to integrate ITS data into planning, operations, maintenance, and project-selection processes.
ITS system needs to be upgraded for increased connectivity to local signal coordination systems brought online by suburban communities.	The traffic management center operates as a separate location and is not integrated into day-to-day agency operations.
Rapidly changing technology offers an opportunity for improved functionality.	Agency policy emphasizes operations and incident management to improve reliability.
Stakeholders	
External	**Internal**
Commuters and freight industry	Traffic operations
Emergency responders	Maintenance staff

Local communities and metropolitan planning organizations	Performance management
FHWA	IT staff
Transit operators	Programming and planning

Chapter 4: Identifying Risks



Summary

This chapter explains the next step in the risk management process: risk identification. In this step, risk workshop participants identify all possible risks, which are analyzed and evaluated in later steps. In this phase, participants do not attempt to evaluate the risks, only document them. Summarized are workshop techniques to stimulate identification of risks.

Risk identification is one part of the three-step risk assessment process, which also includes risk analysis, discussed in Chapter 5, and risk evaluation, covered in Chapter 6.

Risk Identification: First Step of Risk Assessment

Once the objectives have been clarified and their context identified, the process moves to the three-step risk assessment phase, shown in Figure 12. Three components make up the risk assessment: risk identification, risk analysis, and risk evaluation. Although they have similar names, each is a distinct phase in the assessment:

- Risk identification is the process of finding, recognizing, and recording risks.
- Risk analysis is developing an understanding of the risk, including its causes and effects. It provides input to risk assessment and decisions on whether risks need to be treated and the appropriate treatment strategies and methods.
- Risk evaluation is the process of comparing the risks and opportunities with the agency's tolerance or appetite for risk to contribute to decisions on how to manage the risk.

Beginning the Risk Identification Process

The risk teams in this stage use exercises and research to identify as many credible risks as possible. The international guides commonly note that the group should cast a wide net at this stage because risks that are not identified cannot be analyzed or managed.

The most important component of the risk identification stage is to ensure that knowledgeable staff and stakeholders are consulted and the process captures their experience of what risks could occur. Simply discussing processes with experienced personnel can lead to identification of many risks. Most transportation agency risks are not completely new, but have precedents that may have existed for decades. Experienced frontline staff can identify potential risks from past years that newer staff and executives may not anticipate.

The risk guides and case studies emphasize the importance of capturing the experience of staff as one of the most critical components of the risk management process. They emphasize that risk management should be a practical, pragmatic tool that distills staff experience in actionable steps to reduce risk and improve performance. This step may be particularly important in the world of term limits and rapid turnover of agency leadership.

The experience of veteran staff is merged with the results of the context setting, which identifies new elements in the environment, such as changing technology or shifting public opinion. The combination of staff experience and evaluation of the current context is important to the risk-identification process.

Figure 12. The three elements of risk assessment.

Techniques for the Risk Identification Workshop

Risk identification usually occurs in a workshop, often as the next session of the workshop in which the environment and context are identified. The intent of the workshop is to engage all pertinent experts from the organization in contributing to risk identification. The following techniques can be used to stimulate the identification of risks.

Brainstorming

One challenge some organizations face is the silo effect, in which each area of the organization focuses on a niche aspect of the business. A useful technique to stimulate discussions across these areas of expertise is brainstorming. A typical facilitated session takes group dynamics into consideration and successfully engages all participants in the discussion to

collect as many diverse ideas as possible. This can be an informal or structured process. Formal brainstorming involves preparing the participants ahead of time. During the brainstorming session, the team discusses many potential areas of risk. As enough ideas on one topic are generated, the facilitator directs discussion to other topics. The identified risks are recorded.

Interviews

Another format for generating ideas is the structured or semi-structured interview. Structured interviews are useful when the conversation needs to be focused and input is needed on specific questions from multiple people. Often the questions are provided ahead of time, allowing those interviewed to think about and prepare responses. The structured interview also is a good way to ensure that feedback is obtained from a range of personnel, including those who may not have time to attend a workshop or who may not be comfortable participating in a larger group. By keeping the questions open-ended and using follow-up questions, an interviewer can obtain significant information from people with a range of viewpoints. However, interviews do not allow exchange of ideas among members and may have limitations. A variation is the semi-structured interview that allows for brainstorming beyond the structured questions and helps generate more ideas. These interviews are done with a small group, which allows each person to respond while generating some discussion and idea exchange.

Delphi Technique

Another technique is the Delphi process. This approach works well when consensus is necessary. In this approach, a list of questions is developed in collaboration with one or more expert panels. The questions are sent to each panelist or posed in a workshop. Questions are often crafted with a numeric scale of possible responses, allowing for quantification of responses. Averages, the distribution of responses, and other patterns can be analyzed. The panelists respond anonymously and responses are analyzed, combined, and recirculated. As opinions become known, options can be refined and the process can be repeated until consensus is reached. Though time consuming, the benefit is a clear outcome with the degree of consensus, or lack of it, is documented.

Checklists

Another technique that can be used for risk identification is a checklist. Experts develop lists of likely risks taken from past experience. They are shared with the group and used as triggers to determine if the members agree that each of the risks is likely. Checklists can be an effective tool to prompt discussion and quicken the confirmation of already-established risks. It is not a technique used to identify new risks.

Step-by-Step Process Reviews

The Australian risk management guidelines suggest that the risk-identification phase include the group's consideration of all the steps necessary to achieve an objective.[47] The group briefly reviews the steps, inputs, and partners needed to complete an objective, such as delivering a program of projects or deploying a new information technology application. Discussing each step of a process can trigger identification of risks that may not come to mind when discussing the process only in general.

Scenario Analysis

Similarly, scenario analysis is a technique that looks at current or future scenarios and their implications. Considering how risks could occur under different scenarios can stimulate the identification of possible risks that could arise if circumstances change. Scenario analysis can be particularly useful for identifying risks under different funding scenarios. The analysis in these cases would involve looking at best-case, worst-case, expected-case, or status quo scenarios in funding and the consequences of each. Scenario exercises also can be used to look at opportunities and threats that can be expected in the short or long term.

State the Cause and Effect

Another simple but effective tactic is to have the group state each risk in a complete sentence with a subject, verb, and objective. An example is "Increases in binder and aggregate costs will increase our pavement costs and diminish our ability to complete all the paving and preventive maintenance that our asset management plan anticipates." The full statement allows identification of the following:

The source of the risk:	Increases in binder and aggregate costs
The event:	will increase our pavement costs
The effect on objective:	and diminish our ability to complete all the paving and preventive maintenance that our asset management plan anticipates.

The fully articulated risk allows later steps to occur more easily. The statement of potential effect will contribute to the group analyzing the effects of the risk and identifying its root causes. The rise in binder and aggregate prices also will raise issues that could affect other objectives, which also should be considered.

Look for Synergies and Compounding Risks

The lengthy list of potential risks is intended to stimulate thinking and encourage the group to identify linkages to other processes and risks that may be related to their own. As part of the risk-identification process, they are encouraged to think about the multiple linkages or compounding effects of risks and their causes. The compounding effect of small variability spread across multiple activities or programs can be magnified until it becomes a strategic risk. An example is that a 10 percent increase in the cost of one project may not disrupt a program, but a 10 percent cost increase in all projects would. Or a breakdown or delay in one objective could ripple through a program if the program is sequential and relies on the first objective. Delays in training project-inspection staff in how to inspect a new technology such as accelerated bridge construction could affect deployment of an entire program of fast-tracked bridges. The risk identification phase should encourage a broad consideration of linkages and synergies. Potential linkages and synergies should be reported to the managers of risks to other affected areas. Conversely, opportunities identified by one group may provide benefits to others. The point is for groups to think broadly in identifying risks and to consider the compounding effects of risk and opportunities.

The Project Management Institute focuses on the interrelated nature of risks, particularly at the program level.[48] A breakdown in project-support activities can ripple through all projects in a program and create a programmatic or even a strategic risk.

Concurrently, potential opportunities at the project level can be examined for the benefits they could create if applied to all projects across the program.

Categorize the Risks

A helpful tactic when identifying risk is to methodically lead a group through categories of potential risks. They include at least the following as shown in Table 7:

- **Health and safety risks** both to the public and to agency staff and stakeholders, such as contractors' personnel
- **Operational risks,** including variability or uncertainty in agency processes
- **Economic risks**, such as those caused by cost increases or other changes in the underlying economics of a proposed objective or project
- **Political risks** that arise from uncertainties or changes in the political climate, such as shifting public sentiment or a change in political leadership
- **Regulatory risk**, such as that created by new regulatory requirements
- **Information risk** caused by uncertainty or variability in sound information for decision making
- **Natural environment risks**, such as those caused by storms, seismic events, and other natural disasters
- **Fraud or malfeasance risk** that relates to the agency's exposure to criminal behavior, such as theft, collusion, or receipt of benefits for which a party is not eligible
- **Litigation risks** caused by the agency's failure to abide by standards, policies, and statutes

Discussing each type can prompt the recognition of risks or opportunities that may not come to mind initially.

Identify Risks beyond Agency Control

Another key point for the risk team is to identify all risks, even those outside of its or the agency's control. It is important for the agency to identify the outside influences and stakeholders that must be acknowledged in the enterprise risk management effort. A team may initially think that it should only identify risks that it can manage. However, it is important to acknowledge the risks from the external environment so later their effect can be analyzed and reported. The agency may not be able to treat those risks, but it can report them, monitor them, and communicate their effect on the objectives. For agencies that depend on federal funding and national economic and political trends, the external risks can be critical.

Identify Partner Risk

Similar to external risks, the team should note the variability, uncertainty, threats, and opportunities created by partners. Agencies rely on many partners, including planning agencies, law enforcement, resource agencies, FHWA, contractors, material suppliers, and engineering consultants. Changes in the practices of any of these partners can create risks that should be noted. The identification of partner risks can trigger outreach and coordination efforts that may be beyond the control of the program owner. This may lead to escalation of the partner risks to a strategic level so that senior leadership can engage outside constit-

uencies such as FHWA or other state cabinet agencies critical to program success.

Seek Outside Advice

Seeking outside advice is an option for the risk-identification exercise if the leadership lacks confidence in the in-house operation or wants a fresh perspective. The British Treasury's *Orange Book* guide to risk management suggests bringing in outside consultant teams for a top-to-bottom risk identification process if the leadership wants an objective, outside view of a program.[49] This outside perspective may be justified after a major program breakdown or when significant staff turnover depletes the internal expertise in a program area.

Table 7 Risks to a theoretical pavement program

Risks Identified for the Pavement Program	
Economic Risks	The decline in recent years in state revenue will continue and will erode the resources available to our pavement program, particularly for activities that are not eligible for federal funding, such as preservation treatments.
	The size of the Federal-Aid Highway Program is in question and creates uncertainty for long-term resources for pavement rehabilitation and replacement programs.
	Aggregate prices have continued to increase because of a shortage of sources and will erode the purchasing power of the pavement program.
	Volatile oil prices create uncertainty about the long-term cost of our pavement program because they affect binder and hauling prices.
	Consolidation in the pavement industry has reduced competition and appears to lead to higher prices.
	Fewer aggregate sources are available because of the depletion of resources, industry consolidation, and opposition to new quarries. Prices are rising and sources of stone are decreasing.
Safety Risks	Decline in pavement friction increases the risk of crashes to the public.
	Increasing reliance on nighttime paving to reduce traffic impacts increases risk to staff and contractor employees.
External Risks	Heavier trucks in the agricultural, timbering, and fracking industries are distressing many pavement sections.
	Increased storm events have washed out culverts and damaged pavements to a greater extent than in past decades.
	The department wants to increase the use of low-cost chip seal treatments, but faces opposition from local governments that consider it an inferior pavement product. However, overcoming this opposition would create an opportunity for increased use of chip seals and higher pavement conditions at lower cost.
Information Risks	The department lacks complete asset inventories for items such as guardrail and signs, which complicates efforts to estimate project costs when these items are added to pavement projects.
	The department lacks complete histories of performance by pavement section, which reduces our understanding of how pavements have performed.
	The in-house pavement management system is outdated and is unable to perform important forecasting functions.
Operational Risks	Decision makers still rely heavily on standard worst-first treatments that increase long-term pavement costs.
	Not all staff have been trained in pavement management strategies.

Capture Results

It is important to capture the results of the risk-identification exercise. Ideally, the risk assessment process occurs in a short time period and the identified risks remain fresh in participants' minds. But the exercise may stretch over weeks, so documentation is essential to capture all concepts. In addition, because agency operations and risks are often interrelated, the risk-identification effort can be shared with other groups for consultation. Also, organizing and classifying the risks can lead to insight and recognition that may not be immediately evident during the risk-capture exercises.

Figure 13 Categorized risks to the pavement program.

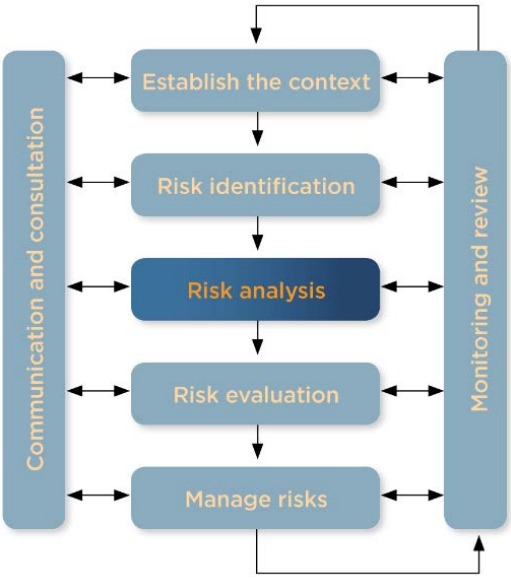
Figure 13 is a graphical depiction of a theoretical set of risks identified by a pavement program risk team. It not only captures a number or risks, but also categorizes and plots them by an initial assumption of their potential impact. The risks are grouped into economic, political, partner, external, information, and operational categories. The risks the group assumes to be more severe are plotted closer to the center of the chart. This provides a representational depiction of the number, type, and initial severity of risks the group identified. It is supported by the documentation in Table 7.

Chapter 5: Analyzing Risks

Summary

This detailed chapter describes the risk analysis process, the means by which risk teams analyze the nature and potential impacts of the risks they have identified. It explains techniques to determine the causes and effects of risks. It also provides analysis tools and tables risk teams can use to deconstruct the elements of a risk and reach consensus on its potential likelihood and consequences.

The chapter supports the step-by-step conduct of a risk analysis workshop or process. The various tools described allow different groups in an agency to conduct numerous risk analyses using similar values and scales so the agency can compare disparate risks by common denominators.



Understanding the Causes and Effects of Risks

In the risk analysis phase, risk teams continue to refine the organization's understanding of the risks to its objectives. They use four steps. First, they identify the causes and effects of risks, usually based on their expert judgment. Second, the participants estimate the likelihood of the risk occurring. Likelihood can range from being certain to occur every year to being likely to occur only once a century. Third, they estimate the consequences from negligible to catastrophic. Fourth, they multiply likelihood by the consequence to achieve a rating: R = L X C. In fact, in some frameworks risk is defined as the likelihood of an impact times its consequence. This simple equation is the basis for all the international frameworks reviewed for this guide.

Like several elements of risk analysis, the result can be qualitative or quantitative, depending on the data available. The result of the qualitative risk analysis phase could be as simple as a team of experts saying that something is likely to occur and it would be bad if it did. Or the risk team participants could produce a probability-based scenario of likelihood and impact that provides a quantified analysis, including upper and lower likelihood levels and impacts. The concepts for the qualitative and quantitative analyses are the same, but they vary on the data points available to analysts.

Uncertainty versus Variability

A paradox of enterprise risk management is that some of the risks with the greatest consequences are the most difficult to quantify, so they lend themselves to the least-complex analysis. As a rule of thumb, the more historical performance data an agency has on an issue, the more it can quantify its risks and impacts. An example is pavement friction. If the agency has good historical data on pavement friction and crashes, it can estimate the corre-

lations between the two. It can estimate the risks to motorists if friction measurements decline across the highway network. Concurrently, if the agency has complete unit-price data, it can correlate changes in them to key inputs, such as prices for oil, aggregates, cement, steel, and labor. With those prices, the agency can quantify the magnitude of risk it faces from commodity price increases.

On the other hand, if the agency is trying to estimate the impact of the next federal transportation act, it has much less historical data. When the next act will be passed, how much it will contain in appropriations, and what new regulatory requirements it will contain cannot be determined by examining past trends.

Agencies need to manage both types of risks, those they can quantify and those they cannot. Some of the tables and values in this chapter are simple, but they are suitable for the hard-to-predict risks that are influenced by highly variable outside events. For other risks, such as those at the project or program level, the agency may be able to use historic trends to develop more robust quantitative analyses.

Some risk management literature differentiates between risks that can be quantified and those that cannot. Risks that can be quantified can often be considered variability. They are risks subject to historical trends and recurring economic or climatic factors that lend themselves to measurement. However, agencies also need to prepare for the "unknown unknowns" that they cannot easily measure. These fall into the category of uncertainty and are best measured through qualitative judgments.

Keeping it Simple, Keeping it Practical

Reliance on staff experience for risk identification, consequence, and likelihood is one example of a larger pattern of advice taken from the risk management literature: keep it simple. One risk management author advocates for a "modesty of tools and a boldness of goals."[50] By this, he means that it is more important for executives to actively manage their known risks than to acquire complex risk analysis tools. Complex tools are used in Wall Street finance and insurance for risk *measurement,* but generally not for corporate enterprise risk *management*. Enterprise risk managers are more likely to rely on the judgment of veteran staff to qualitatively weigh common enterprise risks than they are to invest in complex software systems in an attempt to quantify hard-to-measure risk factors.

The international scan team that examined risk management practices abroad in 2010 came back with the advice to "keep it simple."[51] The experience of staff was the most important component of the risk identification and assessment process.

When an Australian transportation agency risk manager visited the United States in 2012, his advice was to focus on capturing risks identified by staff and applying common sense assessment to them. He discounted the use of complex software tools and mathematical computations. He said his agency would rather manage its risks than spend time managing risk-management software.[52]

Stratified Levels of Impact and Likelihood

The exercises and risk tables that follow are used at all four risk levels: enterprise, program, project, and activity. A risk that is rated very high to an individual activity or a project may be a very low risk to the overall program or enterprise. For the activity owner and his or her team, their highly rated risk may be central to their risk-management efforts. As long as the risk does not create issues for programs or projects, however, it will remain a high risk only at the activity level.

The different levels of risk can be shown in the department's risk website or other central repository of risks. Although the risk may not be critically important to the entire enterprise, the activity risks merit management so they do not increase and their impacts do not extend beyond the activity level.

Determining the Cause of the Risks

Once the risks have been categorized as they are in Chapter 4, the next step is to determine the cause of each risk. This is a necessary precedent for a later step in Chapter 7, which is to manage the risk. If the cause of the risk is beyond the agency's control, treatment may not be possible. For any treatment to be effective, it must address the root causes. Either way, understanding the cause of the risk is important.

Manage, Not Just Treat

An important consideration at this stage is to bear in mind that the evaluation of the root cause precedes the decision on how to "manage" the risk, not just "treat" it. Many frameworks call the next stage the "risk treatment" phase. That name implies that risks are negative and that treatment is a given to reduce threats. However, this guide emphasizes that risks can be positive or negative. The next phase may capitalize on the risk by managing its downsides and exploiting its potential. An example would be turning the risk of a rapidly deteriorating bridge into an opportunity to try a new accelerate-bridge construction technology. The risk that a failing bridge creates safety and performance risk raises the imperative to address the risk quickly. The nuance that risks are not all bad may affect this phase, in which the root cause of the risk is clarified and its effects estimated. What causes the risks and its effects can be an important consideration later in how to treat, transfer, terminate, tolerate, or take advantage of the risk as an opportunity.

Analysis Workshops and Work Groups

The degree of analysis to determine the cause and effect should be commensurate with the degree of impact a risk holds and the familiarity the agency has with the risk. If a new risk arises that could have a major impact but it is little understood by the agency, a formal root- cause analysis may be warranted.

Root-cause analysis is well documented in many fields. The total quality management programs of the 1990s had participants fill out fishbone diagrams to understand factors contributing to poor performance. In recent years, bow-tie diagrams, such as the one in Figure 16, have been widely used. When the agency decides to conduct a root cause analysis, it can rely on many proven tactics taken from the fields of reliability engineering, systems engineering, and emergency planning and preparedness. Several techniques that can be used in risk team workshops are described below.

Bow-Tie Analysis

Figure 14 A bowtie diagram.

Bow-tie analysis is a technique that uses a simple pictorial representation, shown in Figure 14, to present the causes of risks and associated consequences. The left side of the bow tie shows the causes with various controls that prevent the escalation of the risk impact. The right side of the bow tie shows the consequence of each cause and controls that reduce the consequence. The bow tie is easy to understand, but it is limited in how it can show multiple consequences of a cause, so it may be better used for simple scenarios.

SWIFT Analysis

The structured what-if technique (SWIFT) is a method for identifying, analyzing, and evaluating risks. It involves facilitated discussions to engage experts in reviewing and analyzing each risk. The experts use what-if analyses to explore various scenarios. They identify the consequence of each scenario, the likelihood of that scenario occurring, and the level of impact. Results are documented. The output normally involves listing at least the top-ranking risks and how their consequences and impacts are affected by changing scenarios.

Root Cause Analysis

Root cause analysis is a tool to analyze a failure, identify the root cause, and develop treatments to avoid a repeat occurrence of a similar failure. This is often done for major risk-related failures. An example of root cause analysis in a transportation agency is an analysis of the impact of excessive flooding on roadways. Root causes such as undersized drainage structures, increases in paved surfaces, or the connection of unapproved outfalls to the agency drainage structures could be identified. Another example is the excessive damage caused by rock falls in areas where treatments have already been implemented. In this exercise, data on the failure along with available data on similar situations from other states are compiled and analyzed. Experts with knowledge of the specific risk and failure are often involved in the analysis. Various detailed strategies, including root cause mapping, can be used to conduct the analysis. The analysis results highlight the causes of the failure, the assumptions of the analysis, and the corrective action or suggested treatments.

Appropriately Scale the Analysis of Root Causes

Judgment is essential to approach the root cause analysis with the appropriate scale. No analysis may be warranted for the causes of risk that Congress will not appropriate Federal-Aid funds in sufficient amounts. The causes are well discussed in the national media and

probably are beyond the agency's control. Therefore, little time needs to be spent on a complex analysis of the causes. The agency is justified in conducting contingency or scenario planning for cuts in Federal-Aid, but that is separate from a lengthy analysis of the root cause.

However, an analysis of other seemingly uncontrollable risks may be warranted. Initially, an agency may believe it cannot control rising pavement prices because it cannot control prices for oil, aggregates, binder, or cement, but the risk of pavement price increases could be exacerbated by agency specifications or the timing of bid lettings. Judgment is needed to determine if risks are caused solely by external factors or whether factors within the agency's control could have a bearing on the risk level. An agency may face risk of sanction for failing to achieve its goals for awarding contracts to disadvantaged business enterprises (DBE) or women-owned business enterprises (WBE). The agency's policies on requiring performance bonds may be a barrier to such contractors. Accepting more risk by lowering performance bond amounts could result in achieving higher performance on DBE and WBE awards. The root cause of the issue is critical to understanding later how much risk to accept and what treatments could be effective.

Cause-and-Effect Analysis

Cause-and-effect analysis is another technique used to list and systematically analyze the cause and impact of various risks. It is a structured process involving the use of a group of experts to consider multiple likely causes of various risks and determine the root cause of each. The information is presented pictorially it an easy-to-read-format, as shown in Figure 15. Cause-and-effect or fishbone diagrams are two ways to present the information pictorially. This technique can be useful if the group involved has extensive knowledge on the subject of the analysis.

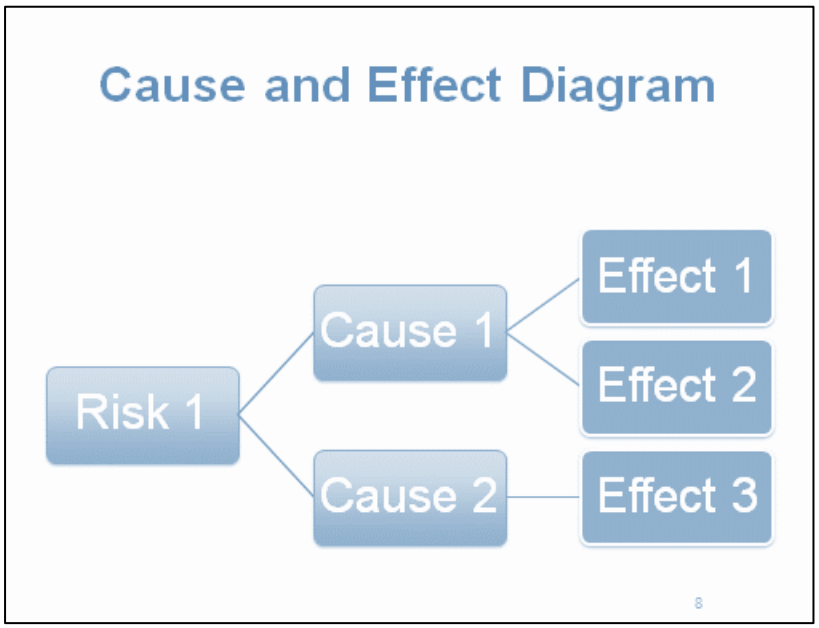


Figure 15. A cause-and-effect diagram.

Monte Carlo Simulation

A Monte Carlo simulation is an analysis technique used to approximate the probability of certain outcomes by computing multiple simulations using random variables. The Monte Carlo routine can be written by a computer coder, or the risk team can use one of the many Monte Carlo routine software packages available on the market. Monte Carlo routines can include running thousands of scenarios. Depending on the number of variables and the computing power available in the workshop, it may be possible to conduct the Monte Carlo

analysis in the workshop itself. Or it may be more efficient to have workshop participants agree on the variables and run the computer simulation later. Either way, the workshop participants, as subject matter experts, can identify the variables and probabilities that can be used in the simulation.

An example is an exercise in which the workshop participants identify the variables and probability for an analysis on whether the 10-year construction inflation rate will exceed a given assumption. The participants can identify their assumptions of the range of possible inflation rates for inputs such as oil, diesel fuel, asphalt binder, cement, aggregates, steel, labor, and so forth. They can identify the high and low inflation parameters for each input and estimate the sensitivity of the input variables to the unit prices for materials. Those inputs and probabilities are entered into the Monte Carlo software, and it runs a set number of scenarios, even thousands. Its output is a statistical analysis of the likelihood of a given inflation rate based on the various probabilities assigned to each input.

Monte Carlo routines are more suited to identifying the probability of an event and less suited to identifying the impact of an event.

Risk Analysis Tools

Once root causes are understood, the risk team participants can move to estimating the likelihood and consequences of the risks. The tools on the following pages provide a common framework for an agency to measure disparate risks with different teams that all use some common denominators. Among the tasks for the agency's risk manager cited in Chapter 2 is developing tools such as those described here. Their use can be explained in training or in the agency's risk management supporting materials or manual.

Public sector risk guides from around the world use a similar suite of tools, although they vary in number and terminology. Some separate each step of the risk-analysis process with its own matrix or tool, while others rely on fewer matrices and have users combine the analysis process into one or two tables. This guide takes a middle ground and includes four levels of risk analysis tools. After the risk team uses these four tools, it proceeds to the risk evaluation and risk treatment phase, which includes further tools. When completed, all the issues are documented in the risk register.

This chapter describes four types of tools for analyzing risks:

- **The consequence levels** include the scales used to analyze the consequence of a risk.
- **The consequence table** is a matrix in which the consequences are described by different types of consequences.
- **The likelihood table** contains the scale used to assess the likelihood of a risk.
- **The risk matrix** illustrates the product of the consequence times the likelihood in a numeric and graphic depiction.

Strengths, Weaknesses of Qualitative and Quantitative Scales

As noted earlier, likelihood values are multiplied by consequence values to achieve a risk score or ranking: R = L X C. The ISO standard and many of the risk guides devote considerable attention to the strengths and weaknesses of different types of scales and calculations for measuring risk.

Some qualitative scales use simple terms, such as “high,” “medium,” and “low.” They are quick and work well when trend or magnitude data are lacking. They allow for the easy categorization of risks and the assignment of risk treatments based on their perceived severity. At its most basic, risk prioritization could stop at that point with the simple categorizing of risks by low, medium, and high levels. The degree of likelihood could be ignored or left to the judgment of the risk managers. However, these scales are not very sophisticated and may not satisfy the need to provide precision or granularity in rankings. Also, people may interpret the scales differently, leading to different conclusions about how much risk treatment is justified.

A hybrid qualitative-quantitative approach is to assign numeric values to the consequence and likelihood scales. A simple scale is designed so that likelihoods that are low equal a value of 1, a medium likelihood equals 2, and a high likelihood equals 3. The same values can be used for consequence, as shown in Figure 16

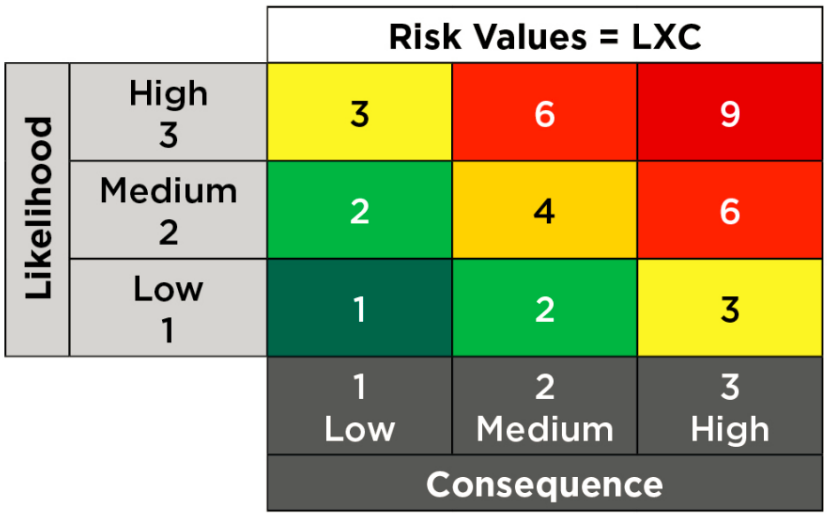


Figure 16 Consequence and likelihood scale.

These scales allow for the simple calculation of likelihood times consequence to derive rankings such as those in Figure 16. A risk with a low likelihood multiplied by a low consequence results in 1 X 1 = 1. The highest risk rating possible in the Figure 16 matrix is a value of 9. The strengths of such a risk matrix are its simplicity and transparency. It allows for the sorting and ranking of risks numerically. However, its weaknesses are its lack of sophistication and its potential ambiguity on what is a low, medium, and high risk. The small difference in scales also leaves many risks with similar rankings, which may complicate deciding how to differentiate the importance of disparate risks.

Possible improvements depend on the quality of data available and the maturity of the risk process. If the data exist, the agency can increase the number and size of values. A matrix such as Figure 16 can be expanded with more consequence levels and values such as those from the New Zealand transportation agency's risk manual which has five levels from 1 to 350 to allow for greater differentiation of risks. The result is greater separation between risk

Table 8 Consequence table

Consequences			
1	**10**	40	70
Low	Moderate	High	Severe

values. For the examples illustrated below, four consequence levels are shown in Table 8. By providing descriptions, the agency can decide how much specificity to provide for the consequence and likelihood scales. The consequence descriptions in Tables 9, 10, and 11 below provide clarity on how to assign the values.

As a general rule, the more homogeneity between risks and the more data available, the more specificity and granularity can be provided to the risk matrix. Among project risk management frameworks, it is common for risks to be measured on the number of days of delay or percentage of project cost change a risk may affect. When risk is measured across many dissimilar categories, it becomes more difficult to find common denominators for measuring risk. Generally, the more dissimilar the risk categories being assessed, the more that professional judgment is needed to differentiate their consequences and likelihood.

Consequence Level Descriptors

As the name indicates, consequence level descriptors identify the number of levels of consequence and describes each. Table 9 illustrates consequence levels for enterprise or strategic risks. The levels are scaled qualitatively from severe to low with a description of each. This consequence table is patterned on those in British and Australian public sector frameworks. It is suited primarily for qualitative analysis of hard-to-measure issues that do not lend themselves easily to quantification.

Note that it uses neutral words such as "affects" rather than "threatens," "delays," or even "increases." This reflects the definition of risk as the effect of uncertainty on objectives and the fact that risks are not always negative. This consequence table could contribute to the evaluation of opportunities as well as threats, uncertainties, or variability. With this table, an issue, event, or thing could be evaluated for both its positive and negative aspects. An agency's use of accelerated bridge construction techniques for the first time brings into consideration the risks of cost, construction quality, agency reputation, and traffic impacts. A neutral consideration of consequences allows the agency to consider issues such as the positive effects on project delivery or public acceptance and balance them with possible consequences of increased cost or the agency's lack of experience with the technology.

Stratified Tools

Enterprise Risk Consequence Levels	
Level of Consequence	**Description or Definition**
Severe	Affects the health and well-being of the citizenry, the agency's ability to comply with statutes, the ability to achieve strategic objectives, or the cost of programs by more than 20 percent
High	Affects the safety of individuals or the ability to achieve program goals or causes a more than 10 percent change in program budgets
Moderate	Affects program objectives or budgets by between 5 and 9 percent
Low	Affects program objectives or budgets by less than 5 percent

The British, Australian, and Canadian guides that focus on agency-wide enterprise risk management emphasize that tools such as consequence tables should be uniform across the department so that different risk teams use comparable scales. This allows different types of risks to be compared with a common denominator. However, those guides do not emphasize managing risks at multiple levels. They focus primarily on senior executives managing the major risks and opportunities to the agency's strategic objectives, such as described in Table 9.

Table 9 Consequence descriptions for the enterprise level.

It may be advisable for an agency to develop different levels of consequence tables for programs (Table 10), projects and activities (Table 11) as well as for the enterprise as a whole.

Table 10 Consequence levels for program risks.

Program Risk Consequence Levels	
Level of Consequence	**Description or Definition**
Severe	Affects the health or safety of individuals, affects the ability to comply with statutes, or has the potential to affect program objectives, budgets, or schedules by more than 20 percent
High	Affects the safety of individuals or has the potential to affect program objectives, budgets, or schedules by more than 11 percent but less than 20 percent
Moderate	Affects program objectives or budgets by between 5 and 9 percent
Low	Affects program objectives or budgets by less than 5 percent

Table 11 Consequence levels for project or activity risks.

Project or Activity Risk Consequence Levels	
Level of Consequence	**Description or Definition**

Severe	Affects the health or safety of individuals, affects compliance with statutes, or has the potential to affect the success of a program
High	Affects the safety of individuals or has the potential to affect project or activity objectives, budgets, or schedules by more than 20 percent
Moderate	Affects project or activity objectives or budgets between 11 and 19 percent
Low	Affects project or activity objectives by less than 10 percent

This is because the ability to provide more quantified analysis may increase as the risk analysis moves down the hierarchy to the program, project, and activity levels. A program, project, or activity manager for a well-established agency function may have voluminous data on the cause and effect of different events or influences. Allowing managers to use quantified scales can give them more granularity in their decision making. In such cases, they may want additional consequence levels to capture more detail on the impact of risks.

Two considerations should be made when using multiple consequence tables:

- To the extent possible, they should be similar across each risk level so that program risks can be compared to one another, project risks compared to one another, and activity risks compared to one another.
- They should be scaled so that the greatest risks can be quantified with enough magnitude to determine if they should be elevated to the next risk levels. For instance, should an activity or project risk be elevated to a program or even an enterprise risk?

Application of the consequence levels to program risks is shown in Table 12. The risks are those identified for a theoretical pavement program. The consequence of each risk is shown in the right column.

At this stage, the risk team participants do not have to predict likelihood. They are capturing the degree of impact that the issue or event *could* create in the program. They will estimate the likelihood of the risk later.

Table 12 Application of consequence levels to the pavement program risks.

Pavement Program Risks			
	Risk Type	**Risk**	**Consequence Lev**
1	**Economic Risks**	The decline in recent years in state revenue will continue and will erode the resources available to our pavement program, particularly for activities that are not Federally eligible for federal funds, such as preservation treatments.	High
2		The size of the Federal-Aid Highway Program is in question and creates uncertainty for long-term resources for pavement rehabilitation and replacement programs.	Severe
3		Aggregate prices have continued to increase because of a shortage of sources and will erode the purchasing power of the pavement program.	Moderate
4		Volatile oil prices create uncertainty about the long-term cost of our pavement program because they affect binder and hauling prices.	High
5		Consolidation in the pavement industry has reduced competition and appears to lead to higher prices.	Moderate
6	**Safety Risks**	Decline in pavement friction increases the risk of crashes to the public.	Moderate
7		Increasing reliance on nighttime paving to reduce traffic impacts increases risk to staff and contractor employees.	Moderate
8	**External Risk**	Heavier trucks in the agricultural, timbering, and fracking industries are distressing many pavement sections.	Moderate
9		Increased storm events have washed out culverts and damaged pavements to a greater extent than in past decades.	High
10		The department wants to increase the use of low-cost chip seal treatments, but faces opposition from local governments that consider it an inferior pavement product. However, overcoming this opposition would create an opportunity for increased use of chip seals and higher pavement conditions at lower cost.	Low
11	**Information Risks**	The department lacks complete asset inventories for items such as guardrail and signs, which complicates efforts to estimate project costs when these items are added to pavement projects.	Moderate

12		The department lacks complete histories of performance by pavement section, which reduces our understanding of how pavements have performed.	Moderate
13		The in-house pavement management system is outdated and is unable to perform important forecasting functions.	High
14	**Operational Risks**	Decision makers still rely heavily on standard worst-first treatments that increase long-term pavement costs.	High
15		Not all staff have been trained in pavement management strategies.	Moderate

Consequence Categories

Once the agency has established the levels of consequence in a generic fashion, those levels can be further defined by category. The identification of the risk categories is a key issue for the agency. The types of risks captured in the consequence table reflect values of most importance. They also are important later when risk-mitigation efforts are assigned. They can be assigned to the program areas associated with the risk categories, or they can illustrate how risks in one area spill over into another. In the pavement program risks, pavement friction appears as a risk that has an impact on the safety program. Therefore, the treatment of the pavement friction risk can have multiple benefits, both in the pavement and safety programs. Similarly, the risk that heavy trucks pose to the pavement program illustrate an issue that may be important to the agency's truck size and weight permitting office. The truck weight issue also could prompt coordination with law enforcement to emphasize enforcement of truck weights. The evaluation of any issue from these multiple perspectives can provide insights into the interrelatedness of risks and treatments. It also demonstrates due diligence in capturing that the agency considered risks from many perspectives.

The areas of risk to be captured in a consequence table can include the following:

- Legal and regulatory compliance risks
- Health and safety risks
- Service delivery risks
- Community and stakeholder impacts
- Environmental impacts
- Reputation and credibility
- Fraud and malfeasance risks
- Litigation and liability risks.

Table 13 describes the risk categories. Note how scales of impact are defined for consistency. Also, the descriptions of consequences are neutral to capture both threats and opportunities.

Table 13. A consequence table for program risks.

Consequence Categories and Descriptions					
No.	**Risk Type**	**Low**	**Moderate**	**High**	**Severe**
1	Legal and regulatory	Affects program budgets or schedules by 1 percent or less	Affects program budget or schedules by between 2 and 9 percent	Affects program budgets or schedules by between 10 and 19 percent	Affects program budgets or schedules by 20 percent or more
2	Health and safety	Creates potential to affect lost-time days to staff	Creates potential to affect serious, debilitating injuries to staff and stakeholders	Creates potential to affect the death of one person	Creates potential to affect the death of more than one person
3	Financial	Affects program, project, or activity budgets by no more than 2 percent	Affects program, project, or activity budgets by between 3 and 10 percent	Affects program, project, or activity budgets by between 11 and 20 percent	Affects program, project, or activity budgets by more than 20 percent
4	Service delivery	Creates no more than 5 percent effect on effectiveness of program or project service delivery	Creates no more than 6 and less than 10 percent effect on effectiveness of program or project service delivery	Creates no more than 11 and less than 20 percent effect on effectiveness of program or project service delivery	Creates more than 20 percent effect on effectiveness of program or project service delivery
5	Community and stakeholder impacts	Temporarily affects the stated objectives of members of stakeholders or community group	Creates a permanent effect on a measureable stakeholder or community value	Creates a permanent effect on more than one stakeholder or community value	Creates a permanent, significant effect on community objectives or stakeholder values
6	Environmental	Creates a minor effect on environmental resources that	Creates a temporary effect on a resource that would trigger re-	Creates a permanent effect on a resource that would be	Creates a permanent effect on multiple resources that

Consequence Categories and Descriptions					
No.	**Risk Type**	**Low**	**Moderate**	**High**	**Severe**
		would not trigger resource agency action	source agency action	recognized by a resource agency	would be recognized by a resource agency
7	Reputation	Creates interest among isolated individuals	Creates local interest at the community or individual stakeholder group level	Generates statewide stakeholder and media interest in the reputation of the agency	Creates state and nationwide impacts on the public perception of the agency that could affect agency reputation and credibility
8	Fraud and malfeasance	Creates an effect on the potential for theft or malfeasance of less than $1,000	Creates an effect on potential for theft or malfeasance of between $1,001 and $5,000	Creates an effect on the potential for theft or malfeasance of between $5,001 and $10,000	Creates an effect on the potential for theft or malfeasance of more than $10,000
9	Litigation and liability	Creates an effect on potential litigation for amounts less than $10,000	Creates an effect on potential litigation for amounts between $10,001 and $20,000	Creates an effect on potential litigation for amounts between $20,001 and $50,000	Creates an effect on potential litigation for amounts more than $50,000

Managing the Large Number of Risks

The completed risk tables can be large. The creation of a naming convention and assignment of categorical risk numbers is probably necessary. The risk identification numbers allow them to be used in complex tables to save space but, more important, to allow them to be searchable in the department's overall risk database. Also, in the risk matrix, it is possible to illustrate with the risk identifiers the large numbers of risks that may need to be shown in the tables and matrices. Figure 17 illustrates how the pavement program risks can be captured in one matrix to illustrate both the initial assumed consequences of the risks and the nature of the risks on the program. The major risks in the pavement program are economic risks, caused by uncertain funding and volatile prices that could have a significant effect on the program's finances and its ability to deliver the quality of pavement service the agency desires. These factors will play a role in the risk plan for each program, project, or activity.

An agency is likely to generate dozens or even hundreds of these types of tables. They can be archived on the risk website and used as background by the risk managers, chief risk officer, and perhaps auditors assessing the thoroughness of the agency's risk management program.

Documenting the Decisions

The groups should document their decisions. Table 12 on the page 67 captures the group's description of the identified pavement program risks and how it has assessed their consequences.

Figure 17 Types of pavement risks and their consequences.

Pavement Program Consequence and Category Table											
Id.	Risk Name	Risk Type	Legal	Safety	Financial	Service Delivery	Community	Reputation	Fraud	Liability
P1	State Funds	Economic			H	H				
P2	Federal Funds	Economic			S	S				
P3	Aggregate prices	Economic			M	M				
P4	Oil prices	Economic			H	H				
P5	Aggregate sources	Economic			M	M				
P6	Friction	Safety		M						
P7	Night Operations	Safety		M						
P8	Heavy trucks	External			M					
P9	Storms	External			H	H				
P10	Chip seal opposition	External			L	L				
P11	Asset inventories	Information			M					
P12	Performance histories	Information			M					
P13	Management system	Information				H				
P14	Worst first	Operational			H	H				
P15	Training	Operational				M				

Likelihood Table or Scale

The next tool or scale the agency risk manager should provide is the likelihood scale. The term “likelihood” is used rather than “probability,” which implies some mathematical precision. Instead, the informed judgment of the participants is compiled and a consensus of the likelihood based on their experience and expertise is used. As Table 14 shows, the likelihood table provides a simple but consistent scale for participants to use in estimating the frequency of the risk. The time frame should be clarified. There probably will be a longer

Table 14 A likelihood scale.

Likelihood Table			
Level	Frequency	Likelihood	Value
Almost certain	Occurs almost annually	95 percent	5
Probable	Occurs approximately once every two years	50 percent	4
Possible	Occurs approximately once every five years	20 percent	3
Rare	Less than once every 10 years	Less than 10 percent	2
Exceptionally rare	Occurs once every 100 years	1 percent or less	1

time frame for major enterprise risks, such as the risk of a hurricane or seismic event. Although the risks may be low in any given year, over a five- or 10-year period they are frequent enough to warrant risk management strategies. Therefore, for enterprise risks such as seismic events or delivery of strategic objectives and major programs the time frame may be 10 years or longer. For an activity or a project, the time frame may be as short as two years. As noted in the discussion of consequence levels, an agency may have different consequence tables for different levels of risk. The same is true for likelihood tables. To the extent possible, however, they should be consistent across the program, projects, and activities and each level should have the same likelihood table.

Note that the likelihood table has five categories, while the consequence table has only four. There is no requirement that the two have parallel scales. This likelihood table includes the fifth category of "exceptionally rare," which allows risk managers to assign values to extraordinary events such as catastrophic earthquakes or other disasters. Events such as Hurricane Katrina or the San Francisco earthquake of 1906 are examples of these types of events. Although rare, their impacts are potentially so great that risk-mitigation strategies such as preparedness and disaster-scenario planning may be warranted. This likelihood table provides values ranging from 5 for events that are almost certain to as low as 1 for events that are exceptionally rare.

The likelihood and consequence tables are combined in the risk matrix table in Table 15. It includes the likelihood and consequence levels with corresponding scores for each. A risk's score is the product of the two. As Table 15 shows, a risk that is "almost certain" and has a "severe" risk level scores 350. A risk that is very rare with low impact scores a 1. Those are the two extremes of this matrix.

Table 15. Risk Matrix values table.

Likelihood and Consequence Matrix, or the Risk Matrix						
		Values	Risk Scores			
Likelihood	Almost Certain	**5**	5	50	200	350
	Probable	**4**	4	40	160	280
	Possible	**3**	3	30	120	210
	Rare	**2**	2	20	80	140
	Exceptionally Rare	**1**	1	10	40	70
			Values			
			1	**10**	**40**	**70**
			Low	Moderate	High	Severe
			Consequences			

Table 16 illustrates the use of the likelihood and consequence values applied to the theoretical pavement program described earlier. The pavement risk group assigned consequence values to each of the 16 pavement risks. They now have assigned likelihood values. Those indicate that the pavement program risk team rates as almost certain to be a factor the unpredictability of federal funding, the impacts of the aging pavement management system, the effects of incomplete asset inventories, the effects of incomplete pavement

histories, and the effects of the lack of training. The other risks are estimated to impact the pavement program less frequently, with the likelihood ranging from probable to rare in a given year. The product of the multiplication of the likelihood and consequence values is shown in the Untreated Risk Value column. Untreated risks values are the initial values, which may be reduced after risk treatments are considered in subsequent steps of the risk process. This list of risks is then sorted by highest to lowest value.

Table 16 Likelihood and consequences of risks to the pavement program.

Pavement Program Risks Before Risk Treatment						
		Initial Likelihood		**Intial Consequence**		**Untreated Risk Value**
ID	Risk	Likelihood	Value	Consequence	Value	L X C
P2	Federal Funds	**Almost Certain**	**5**	**Severe**	**70**	**350**
P13	Management system	**Almost Certain**	**5**	**High**	**40**	**200**
P1	State Funds	**Probable**	**4**	**High**	**40**	**160**
P4	Oil prices	**Probable**	**4**	**High**	**40**	**160**
P14	Worst first	**Probable**	**4**	**High**	**40**	**160**
P16	Industry consolidation	**Probable**	**4**	**High**	**40**	**160**
P9	Storms	Rare	2	High	40	80
P11	Asset inventories	Almost Certain	5	Moderate	10	50
P12	Performance histories	Almost Certain	5	Moderate	10	50
P15	Training	Almost Certain	5	Moderate	10	50
P3	Aggregate prices	Probable	4	Moderate	10	40
P5	Aggregate sources	Probable	4	Moderate	10	40
P8	Heavy trucks	Probable	4	Moderate	10	40
P6	Chip seal opposition	Probable	4	Moderate	10	40
P7	Friction	Possible	3	Moderate	10	30
P10	Night Operations	Possible	3	Moderate	10	30

Figure 18 illustrates the same risks as a color-coded risk map. These formats are typically used in risk management reports to provide at-a-glance indicators of the highest risks at all four levels. Generally, the risks in the red areas are subject to risk treatment and those in the green areas are tolerated. Yellow risks are closely monitored and may be treated. Some

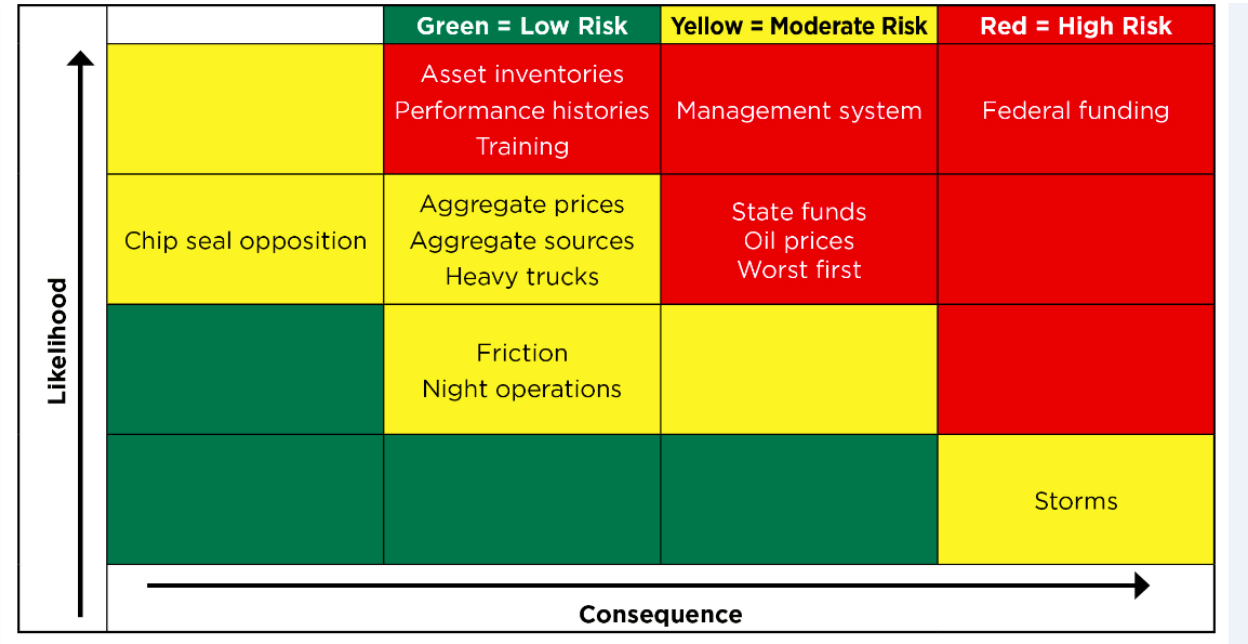


Figure 18. Pavement program risk map.

guides indicate that as part of the establishment of the agency's risk process, rules are written to indicate that risks above a certain value are subject to a required risk-evaluation process, discussed in Chapter 6.

Rating Opportunities

The risks shown in Figure 18 include potential opportunities. The priorities in the risk matrix represent both the degree to which the issue creates uncertainty and the likelihood of it occurring. The matrix illustrates the qualitative magnitude of the threat and the relative magnitude of gain that could be achieved by addressing the issue. Issues on this matrix, such as updating the management system, reducing the use of a worst-first approach, improving training, and reducing opposition to the use of chip seals all represent potential opportunities that may be within an agency's control. The next step involves evaluating the risks, including understanding the cause, effect, and cost to address the risks. If the costs warrant, many of these risks could be addressed and capitalized on as opportunities.

Table 17 is a modification of a threat and opportunity consequence table from the Transit New Zealand *Risk Management Manual*. It provides a continuous scale from substantial threat to substantial opportunity. The consequence values from threats and opportunities can be multiplied by the likelihood to rate both threats and opportunities. The table provides a scale for measuring risks that offer opportunity as well as those that could reduce threats.

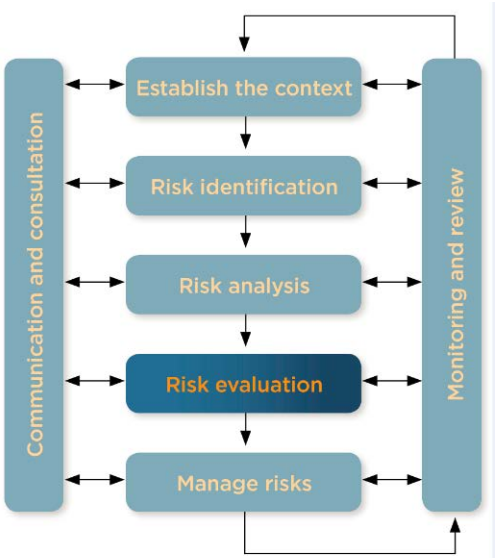
An agency that wants to emphasize the use of risk management to encourage opportuni-

ties can develop similar scales. They can be used to support adoption of new innovations that may bring uncertainty or even threats, but could be justified if they also hold the potential for greater public rewards. The New Zealand consequence table applies to project risk management, but could be modified for any area.

Table 17. A threat and opportunity table.

	Value	Health & Safety	Reputation	Environment	Stakeholder Interest	Cost	Time	Rating
Threat	Substantial	Multiple fatalities	International Media Coverage	Permanent widespread ecological damage	Commission of Inquiry	+$10M	Many years	100
	Major	Several fatalities	Sustained National Media Coverage	Heavy ecological damage, costly restoration	Ministerial Inquiry	+ $1M to $10M	Years	70
	Medium	Serious Injuries	Short-term regional media coverage	Major but recoverable ecological damage	Ministerial Questions or 3rd party investigation	+ $100k to $1M	Months	40
	Minor	Minor Injuries	Local Media Coverage	Limited but medium-term negative effects	Official Information Request	+ $10k to $100k	Weeks	10
	Negligible	Slight Injuries	Brief Local Media Coverage	Short-term damage	Minor Complaint	+ $0 to $10k	Days	1
Opportunity	Negligible	Prevention of Slight Injuries	Brief Local Media Coverage	Short-term enhancement	Letter of support	- $0 to $10k	Days	-1
	Minor	Prevention of Minor Injuries	Local Media Coverage	Limited but medium-term enhancement	Submission in support for agency	- $10k to $100k	Weeks	-10
	Medium	Prevention of Serious Injuries	Regional Media Cover or Short Term National Coverage	Long-term ecological enhancement	Champions in community	- $100k to $1M	Months	-40
	Major	Saving of Several fatalities	Sustained National Media Coverage	Long Term . important ecological enhancement	Small financial contribution	- $1M to $10M	Years	-70
	Substantial	Saving of Multiple fatalities	International Media Coverage	Permanent widespread ecological enhancement	Large financial contribution	-$10M	Many Years	-100

Chapter 6: Evaluating Risks



Summary

This chapter describes the risk evaluation process. It involves comparing risks to the agency's risk tolerance, or risk appetite. Risks exceeding the risk tolerance should be considered for treatment.

For many of the teams evaluating the agency's risk, this will be a relatively brief step. In fact, in some guides it is considered part of the risk analysis process. The bottom line for the risk evaluation step is that the risk teams consider the magnitude of the threat, variability, or opportunity and proceed with the next step, which is deciding whether and how to manage the risk.

The Risk Appetite

In the preceding step, the risk teams analyzed risks and estimated their likelihood and consequences. In this step, the teams compare the threats, opportunities, variation, and uncertainty with the agency's tolerance for risk. This tolerance is often called the risk appetite. The agency director, commission, or risk manager is responsible for articulating the risk appetite, which will vary by program area.

The risk appetite is the threshold or tolerance for risk. The ISO framework indicates that the risk appetite is a defined boundary. Decision makers can compare the quantified risk to that boundary and decide whether to treat the risk or capitalize on its potential. In some public sector cases, such as at the project level, the risk appetite can be clearly defined. The risk appetite may be that the agency is willing to take few risks that could delay a project by more than a given time, say two months. In many other areas of transportation agency decision making, however, the risk appetite cannot be so clearly defined. Defining the risk appetite can be quite subjective for a task such as estimating how much Federal-Aid funding will be available for the agency's bridge program in the 10th year of its asset management plan or how much risk the agency will accept for 500-year floods or major earthquakes. Those risk appetites are much harder to quantify.

To understand why the risk appetite is emphasized in risk management, it helps to understand how it can be applied in a clearly defined manner in other fields. Many risk management concepts come from insurance and finance. Two insurance underwriters may have different business philosophies. One wants to write high-cost policies for high-risk clients, believing that the inevitable claims it will have to pay will be offset by higher premiums. The second insurer wants to write low-risk policies, believing that although it will receive

lower premiums it will be exposed to less claim risk. Similarly, two investment funds can take different approaches to risk. The first seeks high returns, but can only achieve them by investing in high-risk companies, such as technology startups or companies that work in developing countries. The second investment fund seeks lower, more-predictable returns by investing in companies such as electric utilities or grocery stores. The two insurers and two investment funds have different risk appetites. For insurers and investment fund managers, the risk appetites can be clearly quantified or defined. The low-risk insurance company may write no life insurance policies for high-risk clients, such as smokers over age 50. The low-risk investment fund will track the performance volatility of companies and invest only in ones with a record of slow, steady, predictable returns. These risk appetites are clearly defined in the corporate objectives and are issued as decision guidelines to staff. The organizations' actions are tracked to ensure that the risk appetites are not exceeded.

The insurance and investment examples illustrate an important point. The risk appetite should guide staff decision making and reflect the agency's mission, objectives, strategies, and values. If agency leadership can articulate a clear sense of mission, objectives, strategies, and values, it can use them as the basis for articulating a risk appetite.

The British Treasury's *Orange Book* provides the following advice about setting a risk appetite to any board overseeing a major British governmental agency:

> Many board decisions boil down to questions of "what are we are prepared to take on, which risks do we need to reduce, and which risks are we prepared to accept?" "Risk appetite" is the shorthand phrase commonly used to describe where the board considers itself to be on the spectrum ranging from willingness to take or accept risk through to an unwillingness or aversion to taking some risks.
>
> The board will have an appetite for some types of risk and an aversion for others. Decisions depend on the context, on the nature of the potential losses or gains, and the extent to which information regarding the risks is complete, reliable, and relevant. The outcomes of any decision need to be considered both in terms of the consequences of threats and opportunities missed, and are not confined to money—there are risks we (manage) on behalf of the public and the environment, where our appetite may be very low. Outcomes will invariably impact on the organization, its performance, and its reputation.
>
> Acceptance of a level of risk is usually necessary to achieve a certain level of benefit and so sometimes we need to be prepared to suffer some losses if these are outweighed by an overall gain. The risk-benefit ratio is wholly dependent on the context in which the decision is being considered. The determination of risk appetite is about making clear the underlying reasons for accepting a specific level of risk.

Most frameworks include a figure similar to Figure 19. It provides a simple, conceptual approach to the risk appetite. Risks that are of such magnitude that their assessment puts them in the red category are always treated. Risks in the yellow area are always evaluated. Risks in the green area are tolerated or treated with existing processes and controls.

The agency's risk program can articulate risk appetites in various ways. There is no one correct method. The various risk appetites are basically boundaries that can vary by risk type, magnitude, or even timing. The following illustrates some ways risk appetites can be stated.

Values Based

The agency can set some risk appetites based on value judgments. It can state, as England's Highways Agency does, that it has a very low risk appetite for fraud or abuse. Any risk that could open the door for more fraud or abuse could be one that needs to be evaluated, if not treated. Some Australian transportation agencies have low risk tolerances for noncompliance with environmental regulation. They track incidents in which staff are cited for violating hazardous material handling or environmental degradation. A low risk appetite is evident for such risks. Agencies express a low risk appetite for risks to vulnerable populations, such as the elderly, the disabled, or children. Environmental justice communities are another population often highlighted for low-risk tolerance. Although considerable judgment may be needed to discern the degree of risk to a value, citing low risk appetites surrounding these values sends a strong signal to staff to evaluate any potential risks in these areas.

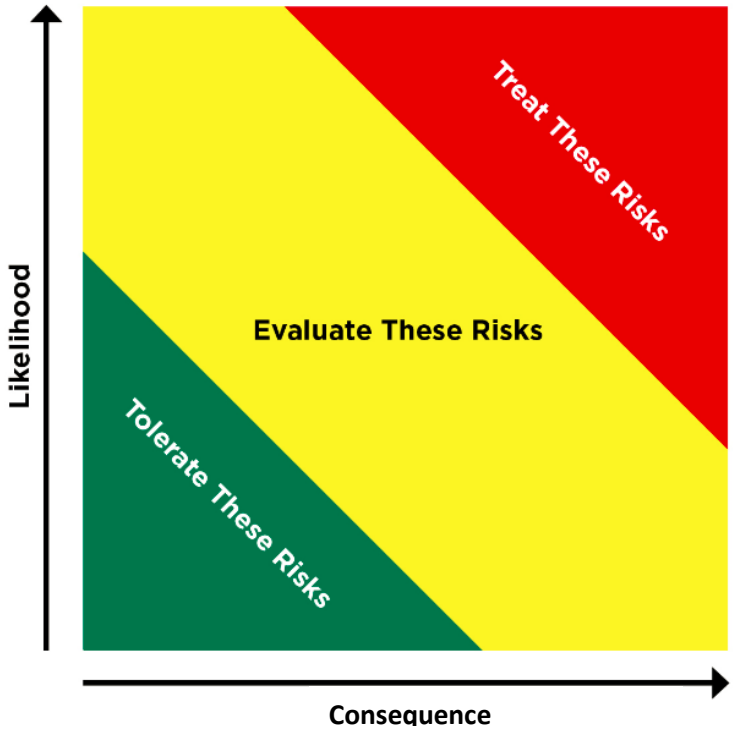


Figure 19. Risk treatment threshold graphic.

Program Based

Similar to the value-based risk appetite, the agency can single out high-profile programs for low risk tolerance. If a state is seismically retrofitting critical bridges on evacuation routes, it could note it has a very low threshold or appetite for risks that could delay the program. Similarly, it may have a low risk threshold for delivery of key safety projects or transit services for the elderly or disabled. Based on the criticality of a program to the agency's objectives or values, a low risk appetite could be expressed. This may be particularly appropriate for programs mandated by a governor or legislature.

Cost Based

The magnitude of potential costs in relation to the overall project, program, or activity can be another risk appetite. Any risk that could cause a project, program, or activity to exceed its budget by 5 or 10 percent could be a flag that the risk needs to be assessed because the risk appetite is exceeded.

Risk Score Based

If the agency has confidence in the consistency of its risk assessment process, it can determine that all risks above certain risk score values must be treated. Midrange risks must be evaluated, while low-scoring risks are tolerated or monitored. These values can vary by program, project, or activity.

Asset Based

The criticality of key assets such as traffic control devices or at-risk bridges can be the basis for expressing a low appetite for risks to those assets. A low risk appetite for a particular bridge or class of bridges can result in them being removed from potential routes for oversized loads or put on lists for increased inspection frequencies. Some states already set de facto risk thresholds for critical routes such as those on the NHS. They tolerate fewer risks to the condition and performance of these critical networks while tolerating lower conditions and higher risks on lower functional classes.

Close Alignment with Performance Management

The close linkage of performance management and risk management can be evident in the setting of risk thresholds for key performance areas. Critical functions such as snow and ice control, clearing of incidents, and operation of IT and telecommunication networks are among the types of operations the agency can single out for low risk tolerance.

This performance-based setting of thresholds can be particularly relevant at the project and activity levels. Many activities are important to the performance of projects and programs. The acquisition of right-of-way or environmental permits is critical for project delivery and the success of key programs, such as safety, bridge, and pavement programs. At the activity level, the manager can set low risk thresholds for risks that would affect critical performance objectives. Although the risk may not be serious enough to rise to the program or enterprise level, it would be of critical concern to the activity manager. Although the agency may not articulate an overall risk appetite for a specific program such as right-of-way acquisition, it may instruct the activity owner to set a risk appetite and to assess risks against it.

It may be obvious by now that there is close alignment between the performance the agency wants to achieve and its appetite for risk surrounding that performance. Risk management is the mirror image of performance management, so risk thresholds at the program, project, and activity levels can parallel the desired performance levels. The following are additional examples:

- Risk appetites can be set for events or issues that could affect—positively or negatively—asset condition levels. Low tolerance may be set for risks that could create significant drops in asset condition, but a high risk appetite may be expressed for adopting new materials or practices that could help achieve asset-condition s.
- Risk appetites for delivering safety projects or programs could be low.
- Risks appetite for desirable but noncritical functions, such as grass mowing, could be high, but the tolerance for not repairing guardrail promptly could be low.
- Risk thresholds for key information services, such as traffic information websites during the hurricane or snow seasons, could be set very low, which would lead to redundancy and backups to ensure continuous performance.

Throughout the performance arena, risk appetites can be set to trigger consideration of risks that could impede objectives for the agency, program, projects, or activities.

Dynamic and Continuous Evaluation of the Risk Appetite

Among the many dynamic elements of the risk management process is the frequent evaluation of risk appetites. They may change based on internal or external events that raise or lower the profile of certain risks. Performance trend data may indicate that risk appetites that were acceptable in earlier years are no longer tolerable. The agency and its employees who help manage risks should be aware that risk appetites may change and should be frequently evaluated.

Risk Prioritization

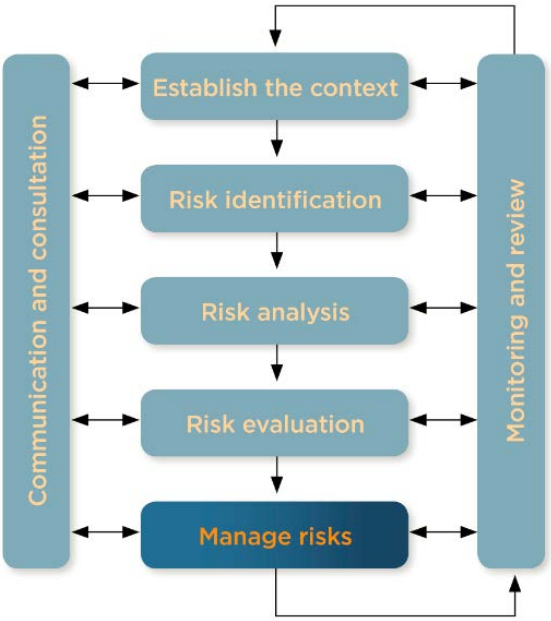
Some risk management practitioners include under risk evaluation risk prioritization as a possible step. As it sounds, this is the process of further ranking or prioritizing risks that have similar expected values. For instance, if a risk workshop identifies many risks with the same expected value of "high" the agency staff may conclude they lack the resources to manage all of them. This may or may not occur in a large agency with extensive resources. However, if it does, the agency could further prioritize risks with similar expected values through methods such as:

Policy Based – If agency policies indicate a priority for addressing certain types of risks they may be further prioritized to address those that adhere to the policy. An example could be the agency prioritizes safety over all other issues. If there is a tie with two risks having the same expected value, the agency's evaluation could lead to a decision to recommend treatment of risks that affect safety above those that do not.

Cost-Based – The agency could pursue risks that are less expensive to address over ones that cost more.

Secondary Benefits or Impacts – If treating or managing one risk creates secondary benefits it may be identified for treatment or management ahead of other risks that do not. Concurrently, if treating one risk creates negative impacts in other areas, it may be prioritized below another risk with a similar expected value.

Chapter 7: Managing Risks



Summary

This chapter explains the five Ts of managing risks: treat, tolerate, terminate, transfer, or take advantage of them. The chapter also discusses the concept of creating a robust and resilient agency to manage risks that cannot be easily treated.

The risk assessment teams recommend how to manage risks after considering their likelihood, consequences, causes, and effects. All the previous steps in the risk process come into play at this stage. If the team believes a risk is within the agency's control, it can recommend strategies to manage or capitalize on the risk. If the risk is beyond the agency's control, it may be highlighted for monitoring and tolerating. In this step, the risk team makes a recommendation based on its earlier work.

At this stage, the teams are ready to recommend strategies to manage the risks. The management strategy or strategies selected should be based on all the work conducted so far to understand the risks, their context, their connections to one another, their causes, and their effects. The point of the earlier steps is to make better decisions at this stage.

Preferably, the same experienced, multidisciplinary people involved in identifying and assessing the risks will be involved in selecting the risk treatments. Additional people should be brought in if the management strategies under consideration depend on or influence other areas, such as legal compliance, budgets, or the operations of other programs.

All recommendations for managing risks need high-level review and approval. Although one group may decide to tolerate a risk because it has a minor effect on its operation, the lack of treatment may have secondary effects on another group. The entirety of how all treatment activities affect the many functions of an agency needs to be reviewed and coordinated at a high level.

The agency needs to consider general guidance on risk treatment-selection decisions and describe some boundaries, similar to the risk appetite. Precise guidance suitable to all decisions is unlikely to be possible because of dissimilarities between risks. In categories where the costs of treatments and benefits can be determined, benefit-cost analysis should be a consideration. However, with some risks, such as those to community values or the agency's reputation, the value of risk treatments or risk tolerance is difficult to measure. Decisions on whether and how to treat risks can include both subjective and objective information on the costs, benefits, and effectiveness of available risk-management strategies.

Based on the identification of risk causes, the risk team needs to develop a list of likely

treatments. The participants need to use their judgment to determine a reasonable list of possible treatments after considering issues such as the agency's legal authority, treatment costs, estimates of treatment effectiveness, and social and cultural acceptability of the treatments. These exercises are best conducted in workshops or through focused interviews.

As with many aspects of a topic as broad as risk management, no hard-and-fast rules exist for estimating risk treatment effectiveness. For well-defined risks, the input-output factors may be well known and may allow risk-reduction effectiveness to be measured. The benefits of crack sealing or bridge beam painting come with some estimate of their effectiveness at reducing asset performance risk. Many other risk treatments are not as well documented and require the risk team's judgment.

Tactics for estimating the effectiveness of risk treatments can be based on the following:

- Known engineering factors, such as the effectiveness of asset treatments or crash-reduction factors
- One-off studies of treatment effectiveness of unique risks
- Agency history or experience
- Staff judgment and consensus

The range of options considered and those discarded should be documented, even if only in bullet or matrix form. This documentation will form part of the risk register and risk record. The information can be valuable to teams who may need to evaluate the risk in future years. It also will demonstrate due diligence and leave an administrative record of the decision-making process. It may be possible to define risk treatment options, their effectiveness, and their costs within a program, but it is less likely that such treatment criteria would apply to other programs.

Managing Outweighs Measuring

The possible lack of precision in the cost-and-effectiveness scale illustrates an important aspect of enterprise risk management. The emphasis is not on significant precision in *risk measurement.* Its greatest value is in generating consensus among veteran staff on how to *manage* what they perceive to be the department's greatest risks.

An example illustrates the difficulty in developing a department-wide set of treatment cost-and-effectiveness tables. The effect of insufficient pavement friction is a risk in the pavement program. It would be possible to develop a treatment effectiveness table based on factors such as additional lane miles of pavement treated, the adoption of high-friction surface treatments, and their costs. Such a table would be useful to the team evaluating that risk. However, insufficient friction is one of 15 pavement risks, so 15 tables would need to be developed for one program. The department's risk management process may examine hundreds of total risks, requiring an extensive effort to create a uniform set of cost-and-effectiveness tables. The tables would need to be updated regularly to reflect current costs and other factors, a significant effort. This guide recommends that each risk team establish its own scale of the possible effectiveness of different treatments, document them, and note the confidence level it has in its scale. To create a uniform set of scales for all risks requires an inordinate level of effort that may not provide commensurate benefits. The larger objective is to manage risks, not to get bogged down in measuring them.

Once the parameters and process of the risk-management decision making process are

documented, the teams proceed to the actual decision making.

The Five Ts

Although other guides include other risk-response categories, this guide recommends five that are summarized below. Intersperse throughout this section are other terms that are used in other risk-management frameworks.

Tolerating the Risk

Tolerating is accepting the risk. It is deciding to take no additional steps other than the normal controls inherent in the current business process. A decision to tolerate a risk could come as the result of several decisions:

- The risk likelihood, consequence, or both are so low that the risk treatment is not cost effective.
- The potential benefits of trying to capitalize on the risk are uncertain or do not appear to be worth the cost of pursuing an opportunity related to the risk.
- No effective control or treatment exists because of the following:
    - The agency lacks the authority.
    - It is outside the agency's capabilities.
    - It is caused by external forces that the agency cannot control, such as national sentiment.
    - The controls are unacceptable for social or cultural reasons.
    - The risk is legally required, such as risks related to environmental permitting or open records laws.

Treating the Risk

Treating is mitigating the risk. It is the most common response to risk assessment. Virtually every program, project, or activity in a department can be construed as an effort to treat one risk or another. Roads are paved to reduce risks to safe travel. Bridges are inspected to reduce the risk of collapse. Drivers are licensed to reduce the risk of unsafe driving. The potential list of risk treatments is nearly endless, so the guide does not try to categorize them all. A wide range of options exists to treat risks.

Most guides offer general advice that is relevant to treating risks or any decision making:

- Do not be overly conservative and try to treat all risks.
- Consider costs and benefits and do not spend excessively to treat a risk unless it is of such social or cultural importance that nonmonetary considerations prevail.
- Ingrain the treatment into the work unit's functions to assure it:
    - Has a clearly assigned owner
    - Has sufficient resources and authority to be accomplished
    - Can be measured and managed
    - Does not violate other legal, social, cultural or operational constraints

The Three Rs for Black Swans and Other Catastrophic Threats

A subset of risk treatment merits special note. This is scenario planning related to catastrophic events that have low frequency but major consequences when they do occur. These are sometimes called Black Swans after a popular book published after the 9/11 attacks, the Great Recession, and Hurricane Katrina. It refers to extraordinary events that are outliers from past experience.

Much modern literature on disaster preparedness notes that modern agencies face great complexity because of the diversity of catastrophes they must consider. Because of climatic changes, increases are expected in rainfall, extreme temperatures, coastal surges, and even droughts. The state of Washington has experienced all four types of events because of its diverse climate and geology. The effects of Hurricane Katrina and Superstorm Sandy illustrate the potential magnitude of such impacts.

Preparing only for climatic disasters is complex enough, but agencies also need to be concerned about terrorist attacks, cyberattacks, and seismic events. Agencies cannot fully treat these major catastrophes and events, nor can they try to tolerate them. International and federal disaster-preparedness agencies recommend taking an all-hazards approach to build a more redundant, robust, and resilient transportation system and transportation agency. This approach suggests that planning for one kind of hazard or threat can increase an agency's or a community's ability to deal with others.[53] The key to this overarching risk management strategy is to gradually and continually focus on increasing the agency's and transportation system's redundancy, robustness, and resilience. These strategies also have been called no-regrets strategies because they have independent value and are useful even if a catastrophic event does not occur.

Redundancy can be defined as duplicative or excess capacity that can be used in times of emergency. On the highway network, redundancy can ensure that roads that may be needed if a major highway is out of commission have the capacity and robustness to serve as an alternate route. For other services, it can mean data systems have backup and offsite redundancy that the agency can rely on during emergencies. For staff, it can include cross training and succession planning. The scope of redundancy covers all aspects of an agency. As agencies consider how to address these major, catastrophic, and largely external events, focusing on adding redundancy can be an effective risk management strategy.

Robustness can be defined as the capacity to cope with stress or uncertainty. As agencies consider how to treat or mitigate major external threats, they can consider the role of robustness. A major bridge in poor condition is normally considered a performance or safety risk, but if it is a weak link for seismic events or other catastrophes, there may be a further imperative to address the structure and make it more robust. Considering whether assets or processes are robust enough to withstand major stresses can be a factor that tips the scale toward risk treatment instead of tolerance.

Resiliency has been defined as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. [54] Enhanced resiliency allows better anticipation of disasters, better planning to reduce disaster losses, and faster recovery after an event. A general risk management treatment related to resiliency is general scenario planning and disaster preparedness. Although planning will not prevent an earthquake or hurricane, it can provide the tools to cope with them more quickly and restore services after them. Disaster-preparedness scenarios can prepare an agency to reduce the impacts of a major event, reducing risk to the public.

Transferring the Risk

Transferring risk shifts risk to another party. ISO refers to this as "sharing" the risk. The most common risk-transfer mechanism is purchasing insurance. This is not common in U.S. public sector transportation agencies, although Washington State DOT and some Australian agencies have insurance coverage against catastrophic events damaging critical structures.

There are some typical risk-transfer techniques that U.S. agencies can adopt. The requirement for contractors to have a performance bond shifts some of the risk from the agency to the bonding company. If the contractor defaults, the bond covers the cost of completing the construction project. Another type of risk transfer is requiring contractors to have insurance for vehicles, workers' compensation, and professional liability. These are long-standing risk-transfer techniques.

Performance contracts can be a form of risk transfer. If an agency contracts with a company to provide performance-based IT support services or if a contractor is required to build a facility and maintain it for a certain period, both instances involve some forms of risk transfer. The risks related to supporting the performance are transferred to the third party.

A few risk transfer practices are possible through agreement. Agencies may strike agreements with local agencies to share unexpected project cost increases if a project is primarily for local benefit. Agencies can require local parties to acquire or donate right-of-way for joint state-local projects if the agency believes the cost of right-of-way is unknown or could be a risk.

Buying purchase options is another form of risk transfer. An agency can purchase an option to buy fuel, salt, or another product at a given price. This may protect against some price-increase risks.

Risk pooling is an option, particularly for local agencies. They join pools with other agencies to share insurance costs and liabilities.

Risk transfer does not equate to risk avoidance. The agency still retains some risk that the insurance, bond, or agreement will not provide complete coverage if a default occurs. Also, risk transfer costs money and the agency may not see a return on that expenditure if the insurance or bond is not needed.

Terminating the Risk

Another risk-response option is to terminate the risk. In terminating the risk, the agency avoids the risk by stopping a practice or eliminating the source of the risk. ISO refers to this as "removing the risk source." PMI uses "avoid". Terminating the risk may be an option if an agency can substitute a high-risk product with a lower-risk one. Or it can involve replacing timber bridges with more durable concrete ones. For many functions, however, agencies cannot terminate the risks. It is inherent in their mission that agencies undertake high-risk functions, such as working under traffic or maintaining roads at night. To the extent that terminating a risk is an option, it should be considered as a risk management strategy.

Taking Advantage of the Opportunity Inherent in the Risk

The final T is taking advantage of the risk. This option has almost as many forms as treating the risk - sharing, exploiting or enhancing the risk opportunity. Risk taking is essential and should be a regularly selected option. Without taking well-reasoned risks, the agency cannot maximize the return to its stakeholders. The key is to take well-reasoned risks in which the rewards are likely to outweigh the negative consequences. Facing risks can compel the organization to consider new options, such as the following:

- Trying new materials and construction techniques to lower costs or improve quality
- Streamlining outdated practices with new technology and procedures
- Dropping low-return assets, processes, or functions to eliminate their inherent risk and consolidating investments into higher-return assets or processes

A measure of success for a risk management program is the number of new innovations it encourages.

Capturing Risk Benefits and Estimating Residual Risk

For risks that are treated, the risk team participants reassess the likelihood and consequence of the risk based on their assumption of how the treatment would affect them. If the treatment eliminates the possibility of the risk occurring, they can re-score the likelihood value to “rare.” Or if they believe the treatment lowers a risk from “severe” to “moderate,” they can record that value. If a risk is not treatable or if they decide to tolerate the risk, the score is not changed. Recall that the risk likelihood and consequence identified in Chapter 5 are for risks before their treatment. At this step, risk team members estimate the degree of effectiveness and recalculate the residual risk, as shown in Table 18.

Table 18 shows the residual risks to the pavement program after treatments have been identified. The pavement risk team developed these recommended management strategies in its workshop based on the treatment effectiveness values participants estimated. The changes are color coded in a heat-map format. As the table shows, the team identified seven risks for treatment. The team lowered the likelihood or consequence values and recorded their logic in Table 19

Table 18. Residual risk after treatment.

Residual Risk After Treatment							
		Likelihood After Treatment		Consequence After Treatment		Residual Risk	Risk Reduction
ID	Risk	Likelihood	Value	Consequence	Value		
P2	Federal Funds	Almost Certain	5	Severe	70	350	0
P13	Management system	Possible	3	Moderate	10	30	-170
P1	State Funds	Probable	4	High	40	160	0
P4	Oil prices	Probable	4	High	40	160	0
P14	Worst first	Rare	2	High	40	80	-80
P16	Industry consolidation	Probable	4	High	40	160	0
P9	Storms	Rare	2	High	40	80	0
P11	Asset inventories	Possible	2	Low	10	20	-30
P12	Performance histories	Possible	2	Low	10	20	-30
P15	Training	Rare	2	Low	1	2	-48
P3	Aggregate prices	Probable	4	Moderate	10	40	0
P5	Aggregate sources	Probable	4	Moderate	10	40	0
P8	Heavy trucks	Probable	4	Moderate	10	40	0
P6	Chip seal opposition	Rare	1	Moderate	10	10	-30
P7	Friction	Possible	2	Moderate	10	20	-10
P10	Night Operations	Possible	3	Moderate	10	30	0

Table 19. Documentation of the team's recommendations for managing pavement program risks.

ID	Risk	Strategy	Rationale
P2	**Federal funds:** The size of the Federal-Aid program is in question and creates uncertainty for long-term resources for pavement rehabilitation and replacement programs.	Tolerate, Treat	External risk is beyond the control of the pavement program and cannot be completely treated or terminated. Recommend scenario planning be conducted to understand the impacts of federal funding reductions. Recommend continued efforts to use chip seals and other low-cost treatments to stretch pavement program funds. Risk remains severe with no change in likelihood or consequence.
P13	**Management system:** The in-house pavement management system is outdated and is unable to perform important forecasting functions.	Treat	Recommend updating the pavement management system to meet agency requirements. Reduces the likelihood of impact from almost certain to possible because of uncertainty about the timing and success of the new system. Consequence level is reduced from high to moderate.
P1	**State funds:** The decline in recent years in state revenue will continue and will erode the resources available to our pavement program, particularly for activities that are not eligible for federal funding, such as preservation treatments.	Tolerate	External risk is beyond the control of the pavement program and cannot be completely treated or terminated. Recommend scenario planning be conducted to understand the impacts of state funding reductions. Recommend continued efforts to use chip seals and other low-cost treatments to stretch pavement program funds. Risks remain high with no change in likelihood or consequence.
P4	**Oil prices:** Volatile oil prices create uncertainty on the long-term cost of our pavement program because they affect binder and hauling pric-	Tolerate, Treat	Risk is largely beyond agency control and cannot be completely treated or terminated. Recommend continued research on binders and other materials to reduce oil price impacts.

ID	Risk	Strategy	Rationale
	es.		
P14	**Worst first**: Decision makers still rely heavily on standard worst-first treatments that increase long-term pavement costs.	Treat	Recommend treating this risk through training and policy to reduce reliance on worst-first-only strategy. This strategy is noted as a high priority because of the low cost of implementation and potential high reward. Likelihood of risk is reduced to rare, but consequence remains high.
P16	**Industry consolidation**: Consolidation in the pavement industry has reduced competition and appears to lead to higher prices.	Tolerate, Treat	This risk is largely beyond agency control. Recommend monitoring this trend and consulting with antitrust officials, if warranted. Risk remains high. Recommend conducting anti-collusion analysis to monitor bidding practices.
P9	**Storms:** Increased storm events have washed out culverts and damaged pavements to a greater extent than in past decades.	Tolerate, Treat	Risk must be tolerated, but some treatment is possible through conducting scenario planning and emergency-response preparedness.
P11	**Asset inventories:** The department lacks complete asset inventories for items such as guardrail and signs, which complicates efforts to estimate project costs when these items are added to pavement projects.	Treat	Recommended continued effort to develop asset inventories and improve estimating of project costs when non-pavement elements are included in pavement projects. Likelihood and consequence are reduced by treatment.
P12	**Performance histories:** The department lacks complete histories of performance by pavement section, which reduces our understanding of how pavements have performed.	Treat	Recommend treating risk through developing pavement histories as part of an effort to develop a pavement management system. Likelihood and consequence are reduced by treatment.

ID	Risk	Strategy	Rationale
P15	**Training:** Not all staff have been trained in pavement management strategies.	Treat	Recommend treating risk through training. This treatment creates synergy with the pavement management and worst-first strategy. Likelihood and consequence are reduced.
P3	**Aggregate sources:** Aggregate prices have continued to increase because of a shortage of sources and will erode the purchasing power of the pavement program.	Tolerate	Risk is largely beyond agency control and remains moderate. Recommend continued pavement research to determine if lower-cost aggregates can be used with good results.
P5	**Aggregate prices:** Fewer sources of aggregates are available because of the depletion of resources, industry consolidation, and opposition to new quarries. Prices are rising and sources of stone are decreasing.	Tolerate	Risk is largely beyond agency control and remains moderate. Recommend continued pavement research to determine if lower-cost aggregates can be used with good results.
P8	**Heavy trucks:** Heavier trucks in the agricultural, timbering, and fracking industries are distressing many pavement sections.	Treat	Recommend coordination with truck size and weight permit staff and law enforcement. However, effectiveness is assumed to be low and risk level remains unchanged.
P6	**Chip seal opposition:** The department wants to increase the use of low-cost chip seal treatments, but faces opposition from local governments that consider it an inferior pavement product. However, overcoming this opposition would create an opportunity for increased use of chip seals and higher pavement conditions at lower cost.	Treat	Recommend risk be treated through training in item P15. Risk is lowered through treatment.

ID	Risk	Strategy	Rationale
P7	**Friction levels:** Decline in pavement friction increases the risk of crashes to the public.	Treat	Recommend treating risk to the extent that pavement budget allows. However, analysis assumes that limited funding will constrain the effectiveness of treatment, so the risk remains unchanged.
P10	**Night operations:** Increasing reliance on nighttime paving to reduce traffic impacts increases risk to staff and contractor employees.	Tolerate	Recommend that existing controls on this risk be retained through policy and training. Risk level remains unchanged.

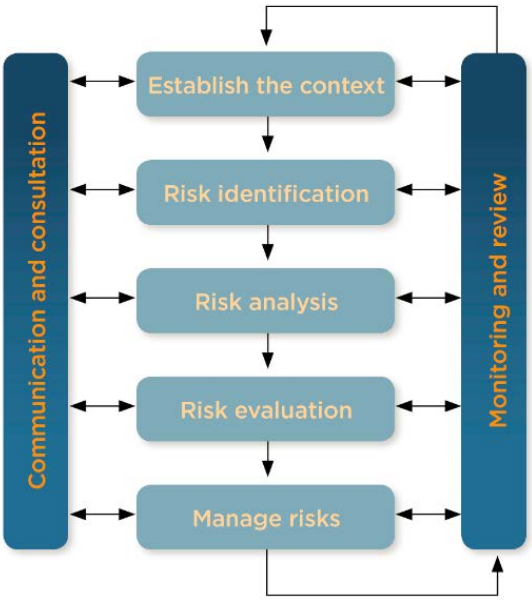
Tables 18 and 19 provide inputs to the risk register for the pavement program, which contributes to the agency-wide risk register. The two tables summarize the treatment strategies, but also give an approximation through the risk-reduction number of the magnitude of benefit or risk reduction the agency can expect to achieve if it follows through on the risk treatment efforts. The risk management analysis indicates that several of the largest risks cannot be effectively treated, such as state and federal funding risks. However, internal process risks can be treated, triggering recommendations to improve the pavement management system, training, inventories, pavement histories, and staff reliance on worst-first treatments. As can be seen, the identification and treatment of these risks are likely to support the department's pavement objectives and strengthen its performance management processes.

Chapter 8: Communicate, Consult, Monitor

Summary

This chapter explains the ongoing and continuous processes of monitoring the risks and their treatments. It also discusses the parallel process of communicating with stakeholders in the external environment to determine how they and external factors may affect the agency's risk profile.

All risk owners are responsible for communicating and monitoring their risks. The task is particularly important for the director, commission, and agency risk manager. It is important for them to establish communication and monitoring channels so that changes in the agency's risk environment can be noted and acted on if needed.



Using the Agency's Risk Process

Now that the agency's risks have been assessed and treatments recommended, the risk management processes described in Chapter 2 are put to full use. The active, ongoing review of the risks and the effectiveness of their treatment are the most important aspects of the risk management process. As discussed in Chapters 6, and 7, many of the risk identification and assessment processes are relatively simple. Each, however, serves as a trigger to engage agency personnel in thinking about the risks their agency faces and how they could address them. The real benefits of risk management come from acting on the information.

This guide assumes that risk management is most useful when agencies have robust performance management systems in place. During communication and monitoring, the risk management program operates in parallel with the performance management functions. As agencies measure progress toward performance, they also measure progress toward managing the risks to the performance. Risk management updates are performed in parallel with performance updates.

Communication and monitoring are continuous efforts in the risk management process. They are continuous functions that are highlighted during the following:

- Monthly performance review meetings
- Presentations to the commission, if the agency has one

- Performance reviews of managers and other risk owners
- Updates of agency budgets, STIPs, TIPs, and long-range plans
- Transportation Asset Management Plan, Highway Safety Plan, and Highway Safety Improvement Plan

While the bullets above refer to specific events or reports, updating the risk registers can occur any time events warrant. Midstream events, such as natural disasters, legislative action, economic crises, or performance breakdowns, can trigger a risk rating update and prompt an agency to increase its focus on a risk or downgrade risks that are mitigated.

The agency can adopt rules for updating the risk register, including who is authorized to do so and how changes are archived. The rules also can address the notification of other units that may be affected by the risk.

Populating the Risk Register

The central tool for the ongoing management of risks is the risk register. Usually generated as a spreadsheet, it has an intentionally simple format that allows for frequent updates. It includes only enough narrative to communicate its major points. It is intended to be a day-to-day working tool, not a highly polished report that is difficult to update.

Risk registers are difficult to illustrate in the portrait layout of reports such as this guide because they tend to be wide, horizontal spreadsheets, as Figure 20 shows.

From left to right, the columns include the following information:

1. Risk identification number
2. Description of the risk
3. Types of risks involved
4. Impact of the risks, both positive and negative
5. Risk levels:
    a. Initial likelihood times consequence risk level
    b. Residual risk after treatment
    c. Risk reduction magnitude, highlighted to call attention to the priority of this risk
6. Risk owner
7. Date of last update
8. Summary of the progress or other relevant information
9. Overall status clearly highlighted, information that can be used in status summaries to quickly identify if additional actions are needed to keep the risk reduction effort on track
10. Action required to continue implementing the risk management effort

Most risk registers are similar to this one, but vary depending on the information the agency chooses to include.

Risk Register Pavement Management System Development												
Risk ID	**Risk Description**	**Risk Type(s)**	**Impact**	**Risk Level**					**Risk Owner**	**Last Update**	**Additional Comments**	**Status**	**Action Required**
P13	The in-house pavement management system is outdated and is unable to perform important forecasting functions.	Informational Operational	Lack of modern system impedes decision making while updated system could improve pavement programming, improve program effectiveness.	Likelihood		Consequence		Total Risk	Meredith Pavement, Pavement Program Manager	Oct. 2016	Development of new PMS underway and milestones to date achieved. Project nearling 50% completion with customer requirements met to date.	Good	Continued diligence on managing contractor and meeting customer requirements.
				Description	Value	Description	Value						
			Initial Risk Level	Almost Certain	5	Severe	40	200					
			Residual after Treatment	Possible	3	Moderate	10	30					
			Risk Reduction Value	**High**				-170					

Figure 20. A complete risk register.

The Figure 20 risk register is more detailed than some. A similar but simplified example is shown in Figure 21. How much detail to include is subjective and based on the risk manager's preference.

Risk Register Pavement Management System Development						
Risk ID	**Risk Description**	**Untreated Risk Value**	**Treated Value**	**Comments**	**Status**	**Action Required**
P13 Owner Meredith, Pavement Program Lead	The in-house pavement management system is outdated and is unable to perform important forecasting functions.	**200**	**30**	Development of new PMS under way. Milestones to date achieved. Project nearing 50% completion with customer requirements met to date.	Good	Continued diligence on managing contractor and meeting customer requirements.

Figure 21. A simplified risk register.

These registers and the risks in them are developed for each individual risk. From them is extracted the information to be included in documents and graphics that summarize this information in a more distilled form. The risk manager needs the detailed information in the risk register, but it is cumbersome for senior officials to handle when considering a large number of registers. Further condensing of the information is useful for efficient communicating it internally and externally. An example of a condensed a risk map is shown in Figure 23.

The Risk Map

The risk map in Figure 22 is often used to visually illustrate the risks being managed in a given program or by a particular risk manager. The arrows and representation of the dual positions of the risks show how much the risk treatments are expected to reduce the risks. These visualizations are not intended to be to scale nor to represent precise effects. Instead, they are icons that quickly communicate the priorities of the risk team and the magnitude of results they expect to achieve from the risk reduction efforts. Such images can be effective when included in briefing papers and presentations to illustrate the risk-reduction priorities of the team. They provide a shorthand summary that illustrates the following:

- Risks that have been considered
- Strategies that are in place to manage those within agency control
- Expected results
- Risks that are beyond agency control and must be tolerated

Figure 23 illustrates an example of how the pavement program risk status can be extracted from the risk registers and summarized into a dashboard for that set of risks. This type of dashboard can be included on the risk webpage and used in briefings to leadership and

staff to summarize progress, status, and any needed corrective actions.

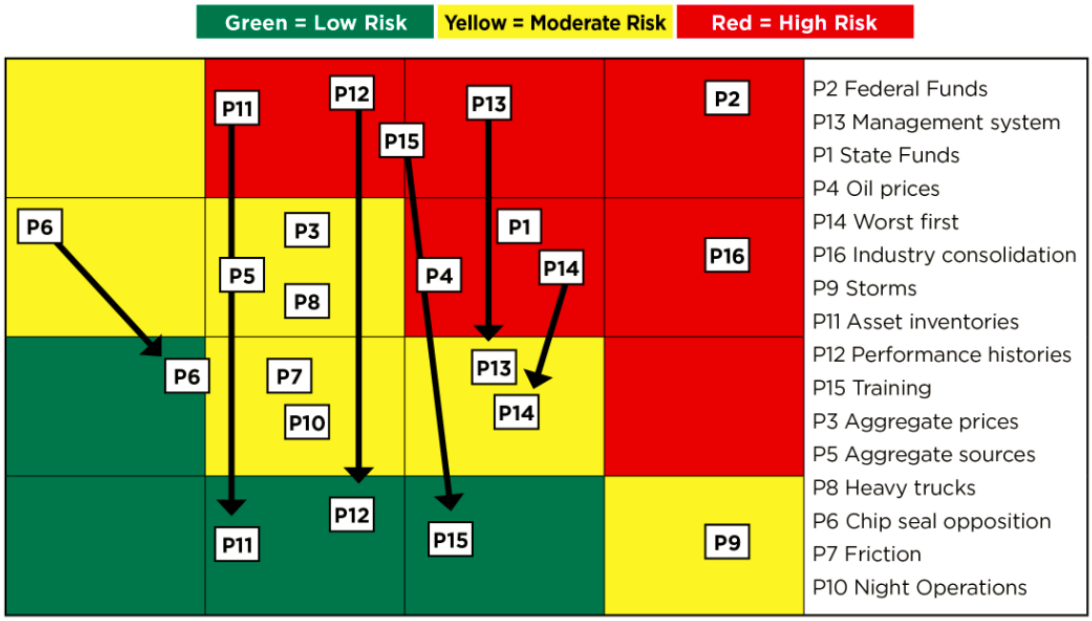


Figure 22 A risk reduction map.

Status Update Pavement Program Risk Management								
		Residual Risk	**Risk Reduction**		**Schedule**	**Budget**	**Requirements**	**Overall Status**
P13	Management system	30	-170	↑	Good	Good	Good	Good
P14	Worst first	80	-80	●	Acceptable	Good	Minimum	Acceptable
P15	Training	2	-48	↓	Behind	Over	Minimum	Poor
P11	Asset inventories	20	-30	●	Acceptable	Good	Minimum	Acceptable
P12	Performance histories	20	-30	↑	Good	Good	Good	Good
P6	Chip seal opposition	10	-30	↑	Good	Good	Good	Good
P7	Friction	20	-10	○	Acceptable	Good	Minimum	Acceptable
P2	Federal Funds	350	0	Monitoring this risk. No management of it.				
P1	State Funds	160	0	Monitoring this risk. No management of it.				
P4	Oil prices	160	0	●	Acceptable	Good	Minimum	Acceptable
P16	Industry consolidation	160	0	●	Acceptable	Good	Minimum	Acceptable
P9	Storms	80	0	●	Acceptable	Good	Minimum	Acceptable
P3	Aggregate prices	40	0	●	Acceptable	NA	Minimum	Acceptable
P5	Aggregate sources	40	0	●	Acceptable	NA	Minimum	Acceptable
P8	Heavy trucks	40	0	↓	Behind	NA	Minimum	Poor
P10	Night Operations	30	0	Monitoring this risk. No management of it.				

Figure 23. A scorecard of risk management activity.

Key Risk Indicators as Leading Metrics

Most agencies new to performance management adopt lagging performance indicators. They measure current and past performance, but do not necessarily provide insights into future performance. Lagging measures are useful for many purposes, such as evaluating program effectiveness and understanding if past inputs generated the desired output levels. However, they may not provide insights into future performance if the underlying conditions are changing. Changes in prices, breakdowns in processes, changes in personnel, or emerging requirements could create new circumstances that will keep past performance from continuing in the future.

Mature performance management organizations often include leading indicators that may be predictors of emerging trends that could influence future performance. Examples include the following:

- Significant changes in bid prices that could indicate program funding levels may not generate as much impact as assumed
- Increases in futures prices, such those on the open market for oil, binder, diesel fuel, salt, or cement
- Increases in equipment downtime or staff sick days that indicate key operations may not be able to maintain expected levels
- Pending regulatory changes
- Missing early project-development milestones that indicate future bid lettings could be delayed

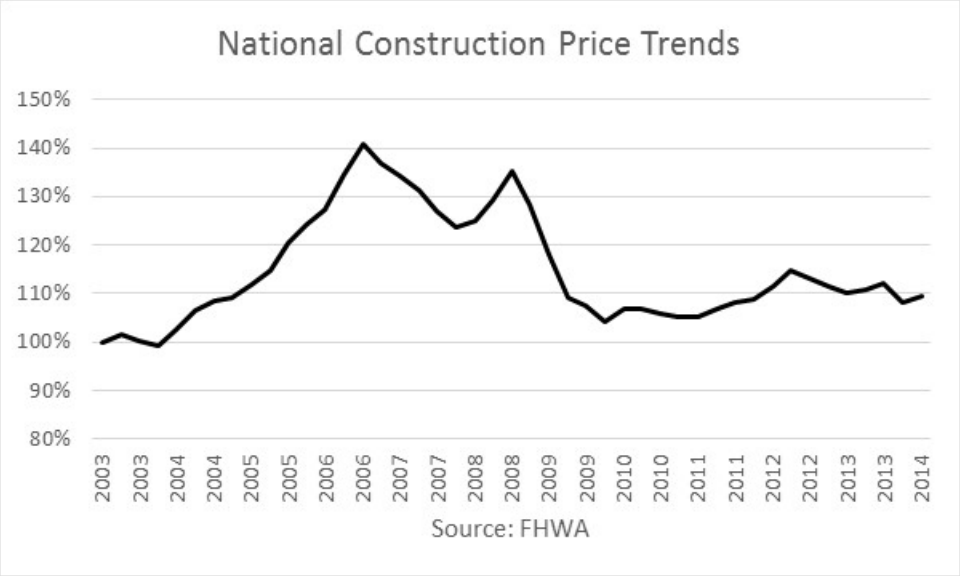


Figure 24. National highway construction price trends.

Figure 24 shows national construction price trend data published by FHWA.[55] It records the substantial increase in construction prices during the economic expansion from 2004

through 2007, followed by a rapid decline, another increase, another decline, and then relative stability for several years. The variability shown in Figure 24 represents a significant risk for agency programs that are forecasting condition trends. The 10-year asset management plans states develop need to include an assumption of expected expenditure levels for bridges, pavements, and other assets and an estimate of how much those levels will achieve in sustaining condition levels. During the risk process, monitoring risks such as futures prices for oil, diesel, gasoline, asphalt binder, cement, and steel can indicate the degree to which budget forecasts are at risk.

These leading indicators can be considered key risk indicators. They are "canary in the coal mine" type indicators that can alert agencies where conditions are developing that put their objectives at risk. The agency can extract from the many risk registers key risks that provide insights on whether future performance is likely to be achieved. Capturing these increasing risks early can allow adjustments that can head off performance problems later.

Extracting key risk indicators can support an agency's performance management objectives and provide the agency with insights into future performance as well as understanding of its past performance.

Communicating with and Monitoring the External Environment

The internal monitoring processes described in this chapter are essential, but are not complete. The agency also needs to monitor the external environment and communicate with key external stakeholders. This is needed to do the following:

- Share with external stakeholders the risks that create uncertainty about whether the agency can achieve its objectives.
- Inform decision makers about the key risks for which their assistance is needed.
- Learn from outside sources changing conditions that may affect the risks the agency faces.

Communicating to external shareholders the agency's risks and how it is managing them can be accomplished by sharing the risk update reports described in this chapter. Discussions of risks also can be included in presentations to metropolitan planning organizations, legislators, the media, and other organizations.

The key consideration is for the agency to frequently communicate with outside stakeholders and seek information that could influence the agency's understanding of its risks.

Consulting with Stakeholders

Closely related to communicating with stakeholders is consulting with them to ensure the agency is addressing their critical risks. This can be particularly important in public agencies that exist to serve stakeholders but also is critical to for-profit companies that must meet customers' demands. ISO notes that a consultative approach with stakeholders can ensure the agency has fully recognized its risk context, that it has understood stakeholder concerns, and that impacts upon stakeholders of risks or treatments are appreciated.

Measuring Risk Management Maturity

As agencies advance in their risk management practices, they may want to assess their progress or maturity. Maturity can be measured for the entire agency or for units within it. This section presents a brief maturity model.

The British Treasury Department and the Australian state of Victoria have developed guidance on measuring the maturity of an organization's risk management processes. Both frameworks resemble the asset management maturity model used in the American Association of State Highway and Transportation Officials (AASHTO) *Transportation Asset Management Guide—A Focus on Implementation*, which also resembles the software development maturity model used in the information technology industry. All allow an agency to assess itself on a four- or five-level scale, from initial consideration of the competency to advanced levels. The maturity model shown in Figure 25 is a composite of the British and Victorian maturity models.

Level 1: Awareness

An agency at the initial level of risk management maturity may have an awareness of what are risks and how they can affect its performance. It may occasionally manage risks, but the efforts tend to be episodic and dependent on the initiative of highly motivated individuals taking it upon themselves to manage particular risks. Or the agency may manage risks based on external pressures to achieve performance in a particular area or prevent a particular threat. Risk management is done on an ad hoc basis without the benefit of a clear process to define, measure, or manage risks. Once the initial risk or set of risks is managed, the risk management process is set aside.

Level 2: Initiating

At the second level of maturity, the agency begins to develop basic risk management processes and procedures. It may identify key risks, such as those to strategic objectives or to critical projects and programs. The risks may be owned by key individuals, but are not widely understood throughout the organization. Follow-up and monitoring of the risks depend on the initiative of the risk owners and are not driven by organization process, cycles, or formal policies. Risks are not clearly defined and the risk management process has not been documented or used as the basis for training. Policies and procedures are not clearly documented.

Level 3: Emerging

At the next level, the agency begins to adopt formal processes, policies, definitions, and procedures to regularly identify and manage risks. Generally, risks that are managed are considered to be threats or variability that could affect performance. Opportunities are not regularly identified, assessed, and capitalized on. The risk process may extend across the key objectives, programs, and projects, but it does not extend to activities or affect frontline workers. Training is provided, but it is limited to key personnel only.

Level 4: Competent

At the competent level, risk management is deeply ingrained in the organization and can be witnessed at the front lines of daily operation. The agency has well-defined policies, procedures, tools, and training that reach the majority of employees. Agency personnel understand the various risk appetites applicable to their programs, projects, and activities. They actively accept well-defined risks when the potential for greater rewards has been defined. Risks and opportunities regularly influence key decisions, such as strategic planning, programming, project selection, materials selection, and other basic processes. The agency regularly monitors its external environment for changes in risks and communicates its risk decisions to stakeholders.

Risk Maturity Matrix					
Element	**Awareness**	**Initiating**	**Emerging**	**Competence**	**Excellence**
Ad hoc	●				
Crisis driven	●				
Requires individual initiative	●				
Only threats managed	●	●			
Definitions and policies documented		●	●	●	●
Spreads to most programs and activities			●	●	●
Training offered but limited			●		
Training widespread				●	●
Policies and procedures mature				●	●
Opportunities managed				●	●
Risk influences planning, programming, and activities				●	●
Monitoring and communicating mature and effective				●	●
Costs and benefits documented					●

Risk Maturity Matrix					
Element	**Awareness**	**Initiating**	**Emerging**	**Competence**	**Excellence**
Opportunities recognized and seized					●
Leading risk indicators used					●
Front lines manage risks and opportunities					●

Figure 25. A risk maturity matrix.

Level 5: Excellence

At the excellence level, the organization has relied on risk management for several generations of decisions and can document the benefits it has achieved. It is able to document the cost savings, performance improvement, and risk-reduction it can achieve. It produces well-understood metrics that indicate how it has reduced risks to its objectives and the costs and benefits of those efforts. Risks are considered at all levels of the organization, training is common, and employees are adept at identifying, measuring, managing, and documenting the results of their risk-management efforts.

Chapter 9: Managing Risks to Key Programs

This chapter illustrates a paradox of U.S. transportation agency risk management. On the one hand, few U.S. agencies practice enterprise risk management that manages risks across their entire organization. For many, the terminology of risk management is unfamiliar. This chapter, however, documents that U.S. transportation agencies do actively manage risks. Risk are managed in the areas of highway safety, bridge design and inspection, some areas of asset management and in many business operations such as purchasing and information technology. However, in the U.S. these risk-based activities are described with non-risk vocabulary. Once U.S. risk-based approaches are re-interpreted as forms of risk management it will be easier for U.S. transportation agencies to "scale up" their current risk programs from the project or program level to the enterprise level. This chapter also provides international examples of how risk management is applied to everyday transportation issues.

This section examines applications of risk management to seven major transportation agency program areas:

- Asset management
- Safety
- External threats
- Finances
- Information
- Business operations
- Project and program management.

Managing Risks to Transportation Assets

The use of risk management to help manage assets is common in Great Britain, Australia, and New Zealand and will become more common in the United States as new asset management plans are developed. The MAP-21 requirement for states to adopt risk-based transportation asset management plans has its precedent in similar requirements in Great Britain, Australia, and New Zealand. By 2017 it is expected that all 50 states, Puerto Rico, and Washington, DC, are to develop risk-based asset management plans.

In Australia, in particular, state and local governments are required to have robust risk management programs that extend to their management of assets. The logic is that it requires a strategic, long-term application of resources to sustain transportation assets in sound condition for the indefinite future. An agency that seeks to achieve a sustainable, well-funded, long-term transportation program will face many uncertainties, variables, threats, and opportunities. As agencies develop asset management plans and programs, they need to identify, measure, manage, and mitigate the risks to their assets and transportation asset management plans (TAMP). Over the 10- year course of an asset management plan, the agency could experience significant variability in funding levels, asset performance, external events such as floods, or changing public demands. Producing a 10-year plan without acknowledging these uncertainties reduces the credibility of the plan and deprives decision makers of critical information.

Examples of Risk in Asset Management Manuals

The following summaries from asset management manuals illustrate the breadth of risk management applications to transportation asset management. This section examines U.S. and international manuals that have existed for many years and risk management applications in the early generation of U.S. transportation asset management plans.

Asset Management Manuals

The Association of Local Government Engineering and the Institute of Public Works Engineering Australia [56] provide a 23-page section on risk in the *International Infrastructure Management Manual* (IIMM). The relevance of the IIMM risk management discussion to transportation asset management primarily is in identifying and preventing physical asset failures. The asset failures referenced in the IIMM risk management discussion often occur incrementally rather than instantly and catastrophically, as they can in an aviation incident or a bridge collapse. IIMM describes "failure" not only as acute and complete, but also as incremental, including the following:

- Structural: when the physical condition of the asset is the measure of deterioration, service potential, or remaining life
- Capacity and utilization: when it is necessary to understand the degree to which an asset is under-or over-utilized compared to the desired level of service

- Level-of-service failures: when reliability or performance targets cannot be met
- Obsolescence: when technological change or lack of replacement parts renders the asset uneconomical to operate
- Cost or economic impact: when the cost to maintain and operate an asset is likely to exceed the economic return expected or is more than the customer is willing to pay

Understanding these failure modes allows the organization to take the appropriate countermeasure. The consequences from these failures can include the following:

- Repair costs
- Income loss
- Service loss
- Death or injury
- Property damage
- Failure to meet statutory requirements
- Third-party losses
- Credibility or image loss

The American Association of State Highway and Transportation Officials Transportation (AASHTO) *Asset Management Guide—A Focus on Implementation* associates risk with uncertainty.[57] While focusing on risk as an aspect of uncertainty, the guide notes that all types of transportation assets have risk that accrue as risks to the agency. This accumulation of risk leads to a recommendation that risk be viewed as a core business driver for the agency, not as an isolated function.

The guide notes that some assets are more important than others in the functional role they play or the number of customers they serve. The guide says the risk identification process should also pinpoint critical assets with high consequences if they fail. This identification can lead to renewed emphasis on the timely treatment of an asset at critical points in its life cycle. The identification also can lead to continuity plans that anticipate continuing service through the unexpected loss of the asset or an emergency response plan to deal with failure if it occurs.

The guide's focus on addressing uncertainty and the disproportionate importance of some key assets leads to an emphasis on network resilience and asset criticality. Assets can be ranked on their importance to public safety, network continuity, connectivity, economic activity, or social well-being. Resilience generally is viewed at a network level, not an asset level. Therefore, redundancy in the highway network can improve resilience.

The guide's focus on criticality leads to the conclusion that consideration of risk management in transportation asset management requires the following:

- Identification of critical assets
- Consideration of the network's ability to cope with identified risk events
- Consideration of risk events that could affect multiple assets, such as an earthquake
- Development of risk management plans that reduce risks to an agency

If the *Asset Management Guide* is reviewed with a broader interpretation of risk, it includes many other references that relate to risk. Two of these perspectives are risk that the asset will fail to perform as desired and risk that the value of the transportation assets will decline. The guide addresses these issues indirectly with little reference to risk, but they easily could be categorized as important risks.

One of the earliest FHWA documents[58] to discuss risk management in asset management was the report on the 2005 international scan examining asset management practices in Australia, Canada, England, and New Zealand. This report noted that by 2005, risk management was well established in the asset management practices of all of the agencies studied. The officials in those agencies viewed risk assessment as a way to educate elected officials and obtain support for asset management.

In England in 2005, risk management was cited in national guidelines as a basic component of good stewardship of assets, along with the use of life-cycle costing, long-term strategies, performance monitoring, sustaining assets, and continuous improvement. Risk management is among a suite of complementary strategies that enhance asset management. The English Highways Agency incorporates risk in numerous policies and guidance documents, such as the code of practice for lighting and standards for bridge project selection.

In New South Wales, Australia, the Roads and Traffic Authority (now called Roads and Maritime Services) included risk as a basic component of its vision, along with ensuring value for money and providing effective governance.[59] The New South Wales Treasury also incorporates risk management as a basic component of sound governance and requires agencies to develop risk management plans for their assets and to ensure compliance with regulatory programs. As a result of this strong focus, risk management permeates Roads and Maritime Services' asset management practices.[60]

The Queensland, Australia, Main Roads Department (since renamed the Department of Transport and Main Roads) likewise incorporated risk as a major departmental consideration, including in its asset management plans and strategies. Risk considerations run through agency operations in areas such as ensuring that sound data support sound decision making. Risk management is evident programmatically in that it is a strong component of the bridge management system, which has guidance that notes that using the management system provides defensible, risk-based decision making on bridge investment.[61] The agency's management system multiplies a bridge's probability of failure by its consequence of failure to assist with investment decision making. The risk of individual bridges is aggregated at a programmatic level, showing total risk by state and region, in addition to the risk to individual structures. The agency tallies department-wide bridge risk and compares it to an optimum or preferred risk. By speaking of bridges in terms of "risk," Queensland officials believe they are using verbiage that elected officials understand.

In the Australian state of Victoria, the VicRoads transportation agency integrated risk management into its asset management practices after analyzing investments and realizing that programs such as grass cutting reduced far less risk than programs such as slope stabilization. As a result, risk became a basic component of programmatic decision making. The incorporation of risk was further emphasized by a 2004 act that reduced road officials' immunity and required them to have in place a process for reasonably reducing risks. The

emphasis on risk in asset management also created renewed interest in pavement friction as a crash-reduction strategy and elevated friction's consideration in pavement management activities.

The Queensland, Australia, Department of Transport and Main Roads *Guide to Risk Management* provides general direction for the agency for comprehensive risk management that is stratified from the top down at strategy, portfolio, divisional, program, project, and operational levels.[62] For each level, it provides guidance, tools, techniques, templates, and direction. The guide notes that Queensland has legislation requiring agencies to adopt and publish risk management plans. The guide says risk management should be embedded in all business activities and should provide a platform for innovation and opportunity. It reiterates the universality of the key steps from communication and consultation through risk monitoring that are common in the earlier risk management frameworks cited. It applies those same risk management techniques to all levels, from the strategic to the operational. In this nesting fashion, the same approach to risk management is incorporated from broad organization-wide strategies to individual projects.

References to risk can be found throughout asset management-related publications developed by the Queensland Department of Transport and Main Roads. For instance, the *Skid Resistance Management Plan* notes that it takes a risk-based approach to managing skid resistance. Low skid resistance and surface texture can increase the risk of crashes.[63] Its risk-based approach is consistent with the department's risk-management requirements. It is proactive, does not rely only on reactive assessment of crash sites, and aims to provide a level of skid resistance appropriate to the road environment. A comprehensive skid-resistance program also helps defend the department in liability lawsuits resulting from crashes.

Risk also is cited in the “Pavement Maintenance” chapter of the Queensland asset-management guidance.[64] It notes that its pavement inspection practices reduce the risk of providing low levels of service and help defend the department in lawsuits. The *Bridge Inspection Manual* integrates risk extensively with high-risk bridges singled out for more frequent inspections.[65] Structure management plans are developed when a bridge's risk reaches a certain threshold. WhichBridge software uses a risk-based multi-criteria calculation to identify bridges for maintenance, repair, and replacement. It notes that certain categories of structures, such as timber bridges built before modern design standards were developed, pose elevated risks and are singled out for specific inspection and treatment. Several asset management publications refer to the Financial Accountability Act of 2009, which states that risk management is a core business function for state and local governments in Queensland.[66] The department also has an Audit and Risk Committee that addresses risk and liability throughout the department.

In 2013, the New South Wales Division of Local Government audited the asset management plans of local governments throughout the state.[67] It noted that asset management reduces risks by doing the following:

- Fully recognizing the resources required to maintain all infrastructure in the local governments
- Providing comprehensive and consistent information on the condition of assets to assist with decisions on maintaining, renewing, and replacing assets

- Communicating to decision makers the assets they own, the services the assets provide, the life-cycle costs of the assets, the asset conditions, and plans for sustaining asset conditions
- Highlighting the life-cycle cost obligations taken on when new assets are built
- Identifying future funding liabilities
- Documenting exposure to natural disasters
- Indicating the risk of infrastructure loss through lack of adequate maintenance.

The New Zealand Transport Agency *Risk Management Process Manual* discusses risk management in detail.[68] The manual defines risk as applied in New Zealand as "the chance of something happening that will have an impact on objectives. It is measured in terms of a combination of the likelihood of an event and its consequence." The manual explains that the intent of the risk management process "is to provide a set of tools that will help minimize threats to Transit's business and maximize opportunities to enhance it. Specifically, the risk management process is designed to raise awareness of threats and opportunities and to minimize such risks as: program/project overrun (in cost or time), litigation, network unavailability/delay**,** death/injury, community and road user concern, and environmental damage**."**

The manual notes that risk management is more than dealing with financial uncertainty and is about managing "all sources of uncertainty that may impact upon (the agency's) ability to meet objectives, obligations, and stakeholder expectations in relation to all anticipated outcomes."

The New Zealand *State Highway Asset Management Plan 2012–2015* includes risk considerations throughout the asset management process.[69] Risk management is applied to both internal staff and suppliers. Managing risks relates to both asset improvement and asset management. The agency has a risk register that it uses as a tool to manage key risks. Contracts stipulate the requirement for risk management to be conducted following the provisions detailed in the *Risk Management Process Manual*.

The Transport Scotland *Road Asset Management Plan* includes a chapter on risk management, illustrating the common use of risk management in that nation's government.[70] Transport Scotland applies risk management at the strategic, tactical, and operational levels to identify, analyze, assess, and manage risks associated with service delivery and in some cases to determine the service required. It notes that a simple definition of risk could be "the chance of something happening that will impact on safety or service." Risk management plays an important role by ensuring that decisions on the control and management of risk are made in an informed, rational, and structured manner. Transport Scotland uses many private contractors to perform maintenance. Inherent in their contracts are specified risk-based activities such as inspections. Road safety inspections that look for items such as missing signs or other immediate hazards are required twice weekly, and detailed inspections are required annually. Serious defects must be addressed on major routes by 6 a.m. the day after they are identified, while less-critical ones are scheduled for repair within 24 hours. Maintenance needs not classified as urgent or safety critical are scheduled on a needs basis using a value-management approach.

In the Australian State of Victoria, the VicRoads *Risk Management Policy* states that risk is

inherent in all day-to-day operations.[71] Risk management, therefore, is not an add-on, but a primary activity of the organization. It says the organization needs to manage risk to enable it to "get on with the job confidently and responsibly, knowing that relevant risks have been identified and dealt with appropriately." It says all staff need to identify, evaluate, and manage risks during their normal business activities.

The policy emphasizes that VicRoads has statutory obligations to ensure that its risk profile is critically reviewed at least annually. It must ensure that its risk management framework is implemented across the organization at all levels and operates effectively to control risks to a satisfactory level. The chief executive will attest in the VicRoads *Annual Report* to implementing an effective risk management system, consistent with Risk Management Standard AS/NZS 31000:2009, and achieving satisfactory risk management outcomes. VicRoads will reinforce a culture of risk management and ensure that risk management principles are adopted in its business procedures. To achieve its risk-management objectives, it will ensure that staff are property trained and that risk management is incorporated in its management systems.

The emphasis on risk-based asset management in Australia was renewed after a court decision effectively revoked the long-standing immunity highway agencies had against claims that infrastructure deficiencies contributed to crashes. As a result, agencies must rely on a "policy defense," or the defense that they have acted prudently by using a risk-based asset management process.[72] By demonstrating the use of a rational, risk-based asset management system, they can show due diligence and provide an effective defense to liability if a crash occurs. The elements of a defensible risk-based asset management program include the following:

- Regular, documented inspection programs
- Documented allocation of funding for repair and maintenance
- Documented competing demands on resources
- Determined intervention levels
- Prioritization actions and documented reasons for prioritization
- Determination if further proactive inspections are required

U.S. Asset Management Plans

Several early generation U.S. transportation asset management plans have been published, and each addresses the risks to its asset management objectives.

New York State Department of Transportation Risk Assessment

The New York State Department of Transportation (NYSDOT) identified the major risks to its transportation assets in its *Asset Management Plan Draft v 05-02-14*.[73] The plan says the agency followed the usual International Organization for Standardization (ISO) seven-step process to develop a risk register for its assets. It identified seven major risks:

1. If federal funding continues to be inadequate and further limited by where it can be used on the highway network
2. If climate change continues to impart a weather pattern with more intense storms and sea level rise
3. If adequate resources are not dedicated to produce accurate, timely, and complete data for all Federal-Aid Highway Program roads
4. If NYSDOT does not provide staff support for the continued implementation of transportation asset management
5. If NYSDOT is unable to properly balance investments across its programs, such as pavements, bridges, safety, and others
6. If trends continue for fewer vehicle miles of travel, urban concentration, higher fuel efficiency vehicles, and heavier freight loads
7. If NYSDOT does not begin to manage highway corridors and establish levels of service based on customer use (i.e., commuter-local, trade, intercity, emergency response, public evacuation, and tourism-recreation.)

Colorado Department of Transportation Asset Management Plan

The Colorado Department of Transportation (CDOT) addressed several risks to its asset in its 2013 *Risk-Based Asset Management Plan*.[74] It followed recognized processes of identifying risks at the agency, programmatic, project, and asset levels. It convened a task force to identify, analyze, and evaluate risks to the department's assets. It developed a color-coded risk rating scale of measuring risks from negligible to catastrophic. It also evaluated the likelihood and consequences of the various risks identified by the task force through a workshop.

It identified agency risks, such as lack of funds to meet asset targets, inability to meet MAP-21 targets on NHS segments under local control, revenue unpredictability, politics and change in department leadership, negative public perception that inhibits ability to garner revenue, not communicating, and getting buy-in within CDOT for asset management.

Risks identified at the program level include unfunded maintenance requirements, a large Interstate 70 project pulling funds from other projects, staff turnover and knowledge loss, data management, project delivery risks caused by organization or systematic issues, and construction cost variation.

At the project or asset level, significant risks were identified as changing climate, increased rainfall, and unstable geology in the mountainous state. Among the project or asset risks identified were flooding impacts, rock falls, landslides, culvert failures, and other issues. Additional risks were tunnel fires, intelligent transportation system traffic control failures, failure of aging small culverts, scope growth in projects, and project delays caused environmental, right-of-way, or utility conflicts. Figure 27 illustrates a CDOT risk register.

				Consequence Score				Other Considerations					
Risk ID	Voted Priority	Event/Occurrence	Likelihood	Safety	Mobility	Asset Damage	Other Financial Impact	Funding	Insurance	Regulatory	Political	Reputation	Risk Score
Agency Risks													
1a	11	Not having enough funds to meet targets due to inflation in construction costs	5	3	4	4	2	√		√	√		19.5
1b	4	Ability to meet MAP-21 targets for NHS segments under local control	5	3	2	3	2	√		√	√	√	15.0
1c	6	Revenue variations/uncertainties – inability to predict/project total funds available to CDOT	5	1	1	2	3	√	√		√	√	10.5
1d	9	Politics in general, combined with leadership changes in the Department	4	1	2	1	2	√	√	√	√	√	7.5
1e	9	Public perception of CDOT (Negative) – resulting in an inability to garner new funds	2	2	4	3	2	√			√	√	6.3
1f	11	Not communicating to and getting buy-in at the appropriate levels in CDOT how the RB AMP works	3	1	1	1	1	√			√	√	3.5
Program Risks													
2a	8	Unfunded maintenance requirements – e.g., regulatory	5	3	3	2	3	√		√		√	15.8
2b	9	Will I-70 viaduct pull funding from other projects	4	2	3	3	2	√	√		√	√	12.0
2d	9	Retirement of key people, loss or turn-over of staff, resulting in loss of critical knowledge	4	3	2	2	3				√	√	11.0
2e	9	Data management (that impacts ability of CDOT to document accomplishments)	5	1	2	2	3			√		√	11.0
2f	9	Project delivery risks due to organizational or systemic issues, e.g., communication, etc.	3	2	1	1	4	√	√		√	√	7.2

Figure 26. An example risk register from the CDOT asset management plan.

Minnesota Department of Transportation

The Minnesota Department of Transportation's *Transportation Asset Management Plan* notes the agency was deeply engaged with risk management for many years before the MAP-21 requirement.[75] It identified asset management "undermanaged risks" that deserved additional attention to accomplish its asset management objectives.

It organized the risks into three levels. Priority one strategies for mitigating undermanaged risks include the following:

- Annually track, monitor, and identify road segments that have been in poor condition for more than five years and consistently consider them when programming.
- Address the repairs needed on the existing South I-35W deep storm water tunnel system.
- Investigate the likelihood and impact of deep storm water tunnel system failure.
- Develop a thorough methodology for monitoring highway culvert performance.
- Develop and adequately communicate construction specifications for overhead

sign structures and high-mast light structures in a total asset management system (TAMS.)

Priority two strategies include the following:

- Collect and evaluate performance data on ramps, auxiliary lanes, and frontage road pavements for the highway system in the Twin Cities metropolitan area.
- Augment investment in bridge maintenance modules and develop related measures and tools for reporting and analysis.
- Include highway culverts in TAMS.
- Place pressure transducers in deep storm water tunnels with capacity issues.
- Incorporate the deep storm water tunnel system in the bridge inventory.
- Develop a policy requiring a five-year inspection frequency for overhead sign structures as well as related inspection training programs and forums.

Priority three includes the following strategy:

- Repair and replace highway culverts in accordance with recommendations from TAMS once it is implemented.

Georgia Department of Transportation

The Georgia Department of Transportation's 2013 *Transportation Asset Management Plan* includes numerous references to managing risks to assets.[76] It does not produce a risk register or quantified ranking of risks and their consequences, but it does integrate the concept of risk-based decision making throughout the document. It also includes an asset management process improvement action plan that calls for developing a robust risk management program. The plan discusses how risk elements are now inferred or implicit in many agency investment decisions. Pavement treatment sections are chosen in part on the risk caused by providing poor pavement to higher-volume roads compared to lower-volume ones. Risks caused by missing or inadequate traffic control devices or by potential structure failures are considered in project-selection processes.

Case Study of Asset Management Liability in Australia

The following case study from New South Wales, Australia, summarizes a landmark case in which a community's asset management practices figured prominently in a court decision on liability when an asset failed.

On June 8, 2007, the Central Coast of New South Wales was impacted by torrential rain caused by an intense low-pressure system a short distance out to sea. The damage from these storms resulted in declaration of a natural disaster. At about 4 p.m. the road above Piles Creek gave way, leaving a 16 by 33 feet cavity. Shortly afterwards, a driver failed to stop and the car fell into the creek. He, his partner, their two daughters, and a nephew were all killed.

A coroner's inquest was conducted to discover the cause of deaths. In 2008 the coroner found that "an investigation into a collapsed culvert and road above Piles Creek resulting in fatalities establishes that Gosford City Council, as the roads authority, did not conduct itself

in a competent and professional manner" on asset and risk management.[77] The coronial inquiry prompted a review[78] of Gosford City Council, which was carried out by independent public administration experts Dick Person and Alan Griffin, to assess the following:

- The council's record and asset management systems at the time of the Piles Creek incident
- The council's response to the coroner's findings

Gosford City Council did not construct the culvert. The road and culvert at Piles Creek were constructed by the state road authority in 1983, and in 1995 responsibility for the road was transferred to the council to become part of its road network. The council neither accepted nor wanted the responsibility for the relevant section of highway and no additional funding was provided by the state road authority. The coronial Inquiry observed that the council's budget for local road maintenance was significant. However, at the time the council's asset management plan showed that the budget was insufficient to maintain current service levels and reported a substantial gap between available funds and required expenditure.

The High Court's decision in May 2001 to abolish the historic legal immunity of road authorities for nonfeasance raised concerns about the possibility of a new and open-ended public liability exposure for road authorities, an exposure that could be uncertain in scope and the management of which could require spending financial resources beyond any existing budget. In abolishing the previous immunity, the High Court clarified that the road authority is not expected to guarantee that all of the road network will be repaired and maintained to any particular standard or otherwise ensure that no hazards exist, but it does have a duty to have an inspection program to identify predictable and remediable defects. If a policy to manage risks and a program to implement the policy are in place, the defects not discovered are outside the bounds of reasonable duty of care.

The origins of the immunity abolished by the High Court in 2001 go back around 400 years and are based on the idea that legal liability was imposed by positive acts causing damage or injury. The law of negligence requiring reasonable care to avoid injury loss or damage did not become consistently applied until half way through the twentieth century.

At the time of the Piles Creek incident, neither the state nor local government was clearly communicating "duty of care" through an asset management plan to the political level. The state road authority did not transfer an asset and risk management plan for the road section, and Gosford City Council was only in the process of developing an asset and risk management plan when the incident occurred. When the Old Pacific Highway was transferred from the state to the local government, there was no effective due diligence process to determine risks and how they should be managed. The legal and community views were that this should have happened. In 2007 Gosford City Council had not yet progressed to clearly communicating risk and what was and what was not being done about the Piles Creek culvert.

Despite the shared accountability historically, the coronial inquiry expressed a community view that "duty of care" for public safety rested with Gosford City Council as the current asset controller. The council's reputation was attacked through the media. This case study shows there was a clear expectation that the council's asset management policy and prac-

tice should have ensured that expenditure was redirected to assets with the highest risk, irrespective of other considerations and priorities.

A 2006 inquiry found that less than 20 percent of New South Wales councils did not have asset and risk management plans. At the time of the Piles Creek incident in 2007, Gosford City Council's asset and risk management practices were similar to, if not better than, most local authorities.

A Case Study of U.S. Transit Agency Risk Management

The Bay Area Rapid Transit Authority (BART) began service in 1972 and has grown to be the fifth busiest heavy rail transit system in the United States and growing. Most of BART's $21 billion in infrastructure is over 40 years old and at or close to the end of its useful life, placing increasing strain on a high performing, high and growing demand service. Six and one-half billion dollars' worth of BART infrastructure is now at poor or very poor condition but BART is rapidly improving asset and risk management systems and processes to manage a transition that will renew and upgrade essential infrastructure.

BART needed a rapid asset and risk management improvement program to manage the next 10 years. Work started in 2012 to develop asset and risk management plans to guide replacing its old fleet of rail cars with over 1000 new cars, while maintaining a safe, reliable system on old infrastructure.

BART implemented a rapid improvement strategy to adapt existing world best practice to BART's needs. BART is implementing parallel improvement in asset management, risk management, knowledge management, workforce planning and strategic planning. In 2013, after one year, BART had developed and reported to its board the first generation of asset and risk management plans. These asset and risk management plans are on an annual improvement cycle and enable the integration of annual budgets, 4-year work plans and the 10-year asset and risk management strategy.

BART identified the value in combining mature Australian asset and risk management practice using the International Infrastructure Management Manual, (IIMM) [79] ISO 31000 and ISO 55000 with the existing expertise within BART. This enabled rapid adaptation of existing Australian templates, processes and techniques to rapidly develop risk management capacity and capability for the U.S. transit agency.

In the first year of the development plan, MAP-21 was announced and BART was well positioned with an implementation plan underway that aligned with MAP-21 objectives. BART communicated known risks and confidence levels of current knowledge (data, systems, processes and expert judgment). The asset management strategy is to rebuild a high performance but old transit system into a new world class transit system over the next 10 years (Building a Better Bart), while showing value for money and managing risk. Managing a major upgrade project on an active transit system will require very high levels of governance, project management, risks management and communication.

To ensure that system reinvestment, risk, and financial stability are adequately considered, BART staff has developed a comprehensive Asset Management Program (AMP) that will fundamentally guide BART's financial planning in coming years. The AMP includes a com-

prehensive risk framework that assesses the likelihood of near-term failure for each asset and the consequent impact on the BART system, rather than merely looking at age or condition as had been done historically.

BART is communicating and managing many types of risk. Safety and reliability is paramount and these risks must be managed. There are also risks to social equity, environment, reputation and managing growth. BART is developing formal evidence based decision processes to integrate annual capital budgets and long-term financial plans going forward. The asset and risk management plans are enabling BART staff and the Board to take a systematic, risk focused approach to funding allocations, screening all projects and operating needs and prioritizing investment of scarce resources accordingly.

The asset and risk management plan manages risk of existing infrastructure in accordance with ISO31000. This is integrated with managing risks associated with renewal and expansion with a 10-year resourcing strategy that balances:

- Strategic plan goals
- Long term financial plan revenue scenarios
- Asset management plan service levels and risks for each revenue scenario.
- Rolling 4-year work plans
- Annual budgets
- Workforce plan needed to enable the resourcing strategy
- Knowledge management strategy to ensure systems, data and processes support the work plans.
- Knowledge management strategy to ensure systems, data and processes support the work plans.

Managing Risks to Highway Safety

Highway safety is a well-established area of risk-based decision making in the United States. What is less common in U.S. highway safety practices, however, is the use of the word "risk" and the terminology of managing risks seen in international highway safety programs. If U.S. officials want to illustrate a risk-based approach to highway safety, they only need to recast some of their vocabulary because their principles are based on solid risk analysis.

This section compares and contrasts international highway safety frameworks with their U.S. counterparts. Both rely heavily on risk-based decision making. The primary difference is that U.S. safety programs tend to describe crash rates, crash factors, and countermeasures, while internationally those concepts are discussed in risk management terminology.

Australian, Canadian, and British Frameworks

Austroads, the association of highway agencies in Australia and New Zealand, published the *Guide to Road Safety, Part 7: Network Crash Risk Assessment and Management,* which takes an explicitly ISO-centered approach to risk-based highway safety.[80] The joint Australia and New Zealand standard on risk management (AS/NZS 4360:2004) is used as the basis and structure for this framework for highway safety. The issues of communication and consultation, establishing the context, identifying risks, analyzing risks, evaluating risks, treating risks, and monitoring and review are discussed. Examples of risk in the road safety context are provided, including those relating to road trauma, legal risk, and risk from adverse public opinion. The document follows the seven steps of the AS/NZS framework and illustrates how each can provide the basis for an important highway safety countermeasures program. The report clearly links the ISO framework to a systematic approach to managing risks to highway traffic safety.

In the "establish context" step, the guide discusses how by establishing the context the agency gains an appreciation of all factors that might influence the ability to meet the intended safety outcomes. These factors could include the external context, stakeholders, relevant strategies, regulatory issues, and financial environment surrounding the safety program.

In the "identify risk" section, the guide describes how to capture and categorize the types of crashes involving vehicles and vulnerable users. It describes categorizing crashes by those involving only the roadway environment, road users, vehicle, environment, and combinations of those categories. It describes the Haddon Matrix, a means for categorizing crashes by the factors of human, vehicle, or road and identifying if the factor occurred before, during, or after a crash. The guide provides examples of how the matrix and other tools can be used to identify the risks to highway safety.

In the "analyzing risk" section, the guide describes how to determine whether to treat the risk and, if so, how. It describes weighing the causes of the risks that will lead later to determine if and how to treat its causes. It notes that often agencies need to take a qualitative approach to analyzing risks because they may not have definitive risk-causation factors

to depend on, particularly for determining causation of crashes in small sample sizes. It describes reviewing data sources—including crash databases, insurance data, road maintenance inventories, enforcement data, and public surveys—to identify crash-causation factors. Where they are available, it encourages the use of crash-causation factors that may apply to statistically significant samples, such as crash causes across an entire network.

As in the ISO framework, the next step is to evaluate and prioritize the highway safety risks. This needs to occur within the reference of the internal and external context established in the first step, particularly the available funding. It says that hot spot—or as the report refers to it, black spot—areas are among the easiest to prioritize, while systemic crashes that tend not to cluster at a given location are more difficult to prioritize. The prioritization occurs by balancing the available resources with expected reductions in crashes. The assumed effectiveness of a given treatment is compared to the cost of the treatment, and benefit-cost comparisons are made between different treatments at different locations. The prioritized list produces both a location-specific list of treatments and systemic treatments that may address crash types such as roadway departure crashes that tend to be spread across a network.

The "treating risk" section involves deploying the potential treatments identified in the preceding step. It notes that highway safety risks can be reduced by reducing exposure to the risk, the likelihood of a crash, or the severity of a crash by creating a more-forgiving environment. Risk treatment is translated into highway safety treatment terms. For instance, risk treatment could involve removing hazards such as trees or utility poles, requiring protective equipment such as air bags or helmets, or reconfiguring the roadway to reduce hazards of sight distance or curvature.

The ISO-based guide also emphasizes the need to monitor and review to ensure that the risk-treatment plan is as effective as hoped and that lessons learned are incorporated into future plans. It notes that some measures may have both positive and negative effects that must be captured and addressed. In summary, the Austroads guide illustrates how the ISO framework could be applied systematically to highway safety programs.

In 2014, Austroads provided the Australian National Risk Assessment Model (ANRAM) as a tool for risk-based improvement of highway safety.[81] It is an Excel-based software that helps road agencies identify fatal and serious injury crash risk across all parts of the road network. ANRAM helps road agencies manage this risk through a mechanism for identifying, measuring, and reporting fatal and serious injury crash risk based on road infrastructure, speed and traffic flow, and fatal and serious crash history. It enables scoping and prioritizing of investment options to address the highest-risk sections on the Australian road network. Guidance is also provided for jurisdictions on implementing ANRAM at strategic and practical levels.

A U.S. international scan report in 2010 noted that risk-based safety approaches were evident in Australia and New Zealand.[82] The New South Wales, Australia, Road and Transport Authority (since reorganized as the Roads and Maritime Services) reported that it relied on risk-based analyses for many safety decisions, such as requirements for graduated licensing of younger drivers, selecting locations for guardrails, and managing pavement friction. In driver licensing and vehicle inspection, the consideration of risk was highly evident. A Nov-

ice Driver Pilot Program was begun as an education program to reduce the number of young driver deaths on state roads. The trial was a joint effort by the agency, the Australian and Victorian governments, and the Federal Chamber of Automotive Industries. The training provides young, provisional drivers with an understanding of their limitations and how they can reduce the risks they face on the road.

A vehicle selection matrix is used as a risk-based procedure for identifying and inspecting heavy vehicles. It improves the intercept rate of high-risk vehicles through a screening process to identify vehicles with historically poor compliance rates. It has been deployed at checking stations to reduce the intercepts of low-risk vehicles and to focus inspection activities on higher-risk vehicles and operators.

The 2011 Australian Automobile Association Road Assessment Program is a cooperative venture by various Australia insurance companies and highway safety advocacy groups.[83] It produces periodic reports of high-risk routes and regions based on crash rates. It reports risk in terms of what it calls "collective risk" and "individual risk," or high-crash rates. It defines collective risk as the density of crashes over a given section of road and individual risk as the risk of a crash per vehicle. The routes are illustrated in a table similar to a risk register in which the five-year crash ratings for 2000 to 2004 are compared to those for 2005 to 2009. The risks are rated as "low-medium" or "medium-high," and each section is color coded similar to risk levels in a heat map or risk register. The reports discuss the treatments that have been applied to the high-risk sections and illustrates the resulting benefit or crash reduction. The report also identifies sections that have not seen reduced crash rates because of treatment. It continues to highlight them in red for "medium-high" risk or black for "high" risk sections in a risk-register-like report card.

England's Department for Transport similarly makes frequent references to risk and risk assessment in its *Strategic Framework for Road Safety*.[84] As with the approaches in the United States and other nations, it prioritizes strategies based on crash history or propensity, which it casts as risks. It focuses on major categories of risks, such as pedestrians. Within the pedestrian group, it further analyzes the risks to subgroups, such as children living in disadvantaged areas. It found substantially higher crash risks for young pedestrians in disadvantaged areas because of greater densities, proximity to higher-volume roads, lack of yards to play in, and cultural factors. This group is identified as high risk for pedestrian casualties and will be the focus of additional risk-reduction strategies. The framework is not substantially different from U.S. approaches, except that it discusses crashes and injuries more frequently in terms of risk and risk-reduction than is common in the United States.

Canada's 2011 *Road Safety in Canada* report includes risk-based strategies that provide road safety professionals with approaches to promote road safety.[85] The nation's Road Safety Strategy specifically targets high-risk groups such as drivers between the ages of 16 and 24, medically at-risk drivers, vulnerable road users such as pedestrians, motor carriers, and high-risk drivers such as those who speed, drive while impaired, or do not use seatbelts.

The focus on risk and risk management is frequent and explicit in the Canadian strategies. The report notes that young drivers comprise 30 percent of the driving population, but account for 40 percent of fatalities and 45 percent of serious injuries, illustrating their higher-

risk potential for crashes. Two-thirds of fatal collisions are on rural routes, creating another higher-risk focus area. The report states that about 20 percent of fatal collisions involve driver fatigue, which could be addressed with public education campaigns about higher risks when driving while tired. The strategy also emphasizes commercial drivers, who have an even higher risk of fatigue-related crashes than the general population. The strategy focuses on on-board recorders to monitor how long a vehicle is driven and other fatigue-reducing measures.

The Canadian report also says that drivers over age 65 account for 17 percent of fatalities although they represent 14 percent of licensed drivers. Part of the greater risk for this population is medical frailty. The report provides guidance for medical professionals for assessing and advising seniors of their risk factors. It also suggests that improved highway lighting could assist older drivers with less visual acuity. It also suggests vehicle features that could help elders, such as larger instrument displays and seat belts and air bags less likely to injure older drivers.

The Organization for Economic Development and Cooperation (OECD) also frequently references risk and risk-based approaches to highway safety.[86] Its 2013 report of international changes in highway safety includes a heat map of all 27 of its westernized, industrial members and illustrates their rate of change in fatalities in shades ranging from green to red. It tracks fatalities of bicyclists, motorcyclists, pedestrians, and vehicle occupants and shows their rate of change from 2000 to 2011. The heat mapping complements other risk-based tools, suggesting which performance measures best capture risk to the public. The OECD report notes that many professionals favor the use of fatalities per 100,000 people to allow the risk of death or injury by transport to be compared to other risk factors in the population.

U.S. Risk-Based Highway Safety Examples

The crash analysis practices and countermeasures described in the international examples are similar to those used in the United States, with the exception of risk-based terminology. The U.S. highway safety community has categorized crash trends and routinely reports on what types of roadways, roadway sections, intersections, vehicles, drivers, and vulnerable road users are most likely to be involved in crashes. Voluminous detail is provided on crash-modification factors and the effectiveness of countermeasures, or risk-treatment strategies. Among the international examples, the AASHTO 2010 *Highway Safety Manual* is the most detailed and comprehensive. Despite its more than 800 pages, its explicit references to risk are relatively limited compared to international counterparts.[87] However, its inferred emphasis on risks and managing risks is abundant. Most sections of the *Highway Safety Manual* could be recast as a risk-management manual for highway safety. Most of what would have to be changed is terminology.

The *Highway Safety Manual* brings statistical rigor to crash analysis and the application of countermeasures. It provides tools for developing and evaluating a roadway safety management program, including identifying hazardous sites, diagnosing conditions, evaluating potential treatments, and evaluating the effectiveness of reducing crashes through programmed projects. These steps are readily identifiable in a risk-management framework such as ISO. Each involves an ISO risk management step, such as identifying a risk, analyzing

its cause, evaluating treatment, treating the risk, and monitoring and evaluating the effectiveness of the risk treatment. The *Highway Safety Manual* does not refer to ISO, but it can be readily translated into an ISO framework.

The *Highway Safety Manual* includes a predictive method to estimate crash frequency and severity. It also includes crash modification factors and complements the large list of crash modification factors at www.cmfclearinghouse.org/. Although crash modification factors are not generally discussed in the United States in a risk-management framework, they are the corollary to risk-based highway conditions. The *Highway Safety Manual* makes frequent references to the relationship to crash modification factors and risks. It notes that if a school is near an intersection, the risk of pedestrian injuries increases. Similarly, the proximity of an establishment selling alcohol increases the risk of pedestrian crashes. Centerline rumble strips may reduce the risks of head-on collisions, opposite-direction sideswipe crashes, and risky passing, while the absence of rumble strips increases the risk of these crashes and behaviors. The crash risks of roadsides and medians that are wide, flat, and clear of hazards can be statistically compared to the higher crash risk of roadsides that are narrow and steep and contain hazards. Although the *Highway Safety Manual* is not portrayed as an explicit highway safety risk management guide, it represents an example of a risk-based approach that is lacking in name only.

One of the more explicitly risk-based U.S. approaches is the FHWA Office of Safety's "Systematic Approach to Safety: Using Risk to Drive Action."[88] The document describes an approach to prioritizing countermeasures when obvious hot spots are not apparent, but crash numbers are high across a network. The approach bears many similarities to Australia's Safe System strategy.

The systemic approach involves widely implemented improvements based on high-risk roadway features correlated with specific severe crash types. The program emphasizes roadway features that correlate to widely dispersed but frequent crashes, such as roadway departure crashes on two-lane, rural roads. The approach provides a more comprehensive method for safety planning and implementation that supplements and complements traditional site analysis. It helps agencies broaden their traffic safety efforts and consider risk as well as crash history when identifying where to make low-cost safety improvements.

Rather than managing risk at certain locations, a systemic approach takes a broader view and looks at risk across an entire roadway system. A system-based approach acknowledges that crashes alone are not always sufficient to determine what countermeasures to implement, particularly on low-volume local and rural roadways where crash densities are lower and in many urban areas where conflicts occur between vehicles and vulnerable road users (pedestrians, bicyclists, and motorcyclists).

The approach focuses on identifying risk factors that involve a number of crashes and proactively improving the roadway features that correlate to them. Potential risk factors can include lane widths, shoulder types and widths, median widths, horizontal curvature, lane delineation and advanced warning, differential speeds between tangents and horizontal curves, presence of lighting, and left-turn phasing.

FHWA advises that its systemic approach complements, and does not replace, traditional

site-specific analysis. Both approaches rely on basic programming elements from the Highway Safety Improvement Program. The systemic approach does not identify the most appropriate approach for individual locations, but instead identifies low-cost, risk-reducing strategies to be applied across broad roadway sectors or multiple intersections with similar characteristics.

Although the approach does not discuss ISO, it presents a six-step process that is a cyclical, continuous improvement process similar to the ISO framework. The FHWA framework:

1. Begin with identifying the crash types and risk factors to be considered. This is based on a prioritized and ranked list of the most-frequent crash factors, such as that young drivers account for 24 percent of all crashes, a disproportionately high number. Another factor could be that intersections account for 42 percent of crashes, at least in the example presented in the exercise. This step is similar to the "establish the context" step in ISO.
2. The second phase is to screen and prioritize the candidate locations. This is similar to the "identify and analyze" steps in ISO. In this step of the FHWA framework, the network elements that represent the locations with the highest crashes are identified, then the risk factors are considered and locations, segments, or roadway features are prioritized. A prioritized list of segments, horizontal curves, and intersections are generated by the presence of the risk factors.
3. The third phase is to select countermeasures, which is similar to the ISO "evaluate risks" step. In this step, a list of safety countermeasures associated with the targeted crash types is identified. The countermeasures are evaluated and screened for effectiveness and cost, and countermeasures for the types of crashes to be addressed across the highway network are identified.
4. The fourth phase combines elements of the ISO steps of evaluating risks and treating risks. In the FHWA framework, a decision process is developed to consider multiple locations that share similar crash characteristics. Then, specific countermeasures for each candidate site are selected. The final step is to prioritize projects or treatments based on funding, timing, and other programming factors. The prioritized list of locations infers a particular order based on the risk factors for a given location or roadway element.
5. The fifth phase is similar to the ISO "treat the risk" phase. In this phase the countermeasures are implemented. This involves balancing systemic strategies with site-specific strategies and projects. It suggests a framework in which agencies can balance the two types of treatments based on their frequency across the network. Urban areas may have more site-specific crash locations, while rural areas may see risks more widely spread across the highway network. In this phase, projects and treatments are selected and applied.
6. The sixth phase involves evaluation, similar to ISO's "monitor and review" steps. The effects of the treatments are monitored by evaluating the change in crash frequency and severity over time, which allows for refinement and improvement of the countermeasures.

The FHWA Office of Safety says the risk-based approach allows an agency to address the high-frequency but widely dispersed crashes across rural highway networks. It also allows a risk-based approach in urban areas to crashes involving pedestrians, bicyclists, and motor-

cyclists.

Another example of where risk is articulated in U.S. highway safety programs is in the High Risk Rural Road Program established in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users and retained in MAP-21.[89] FHWA provides guidance for classifying routes as high-risk rural roads to qualify for treatment under the MAP-21 provisions for such routes. Its guidance includes:

- Identify routes with a fatality rate higher than roadways of similar functional classifications in the state, such as a roadway with a fatality rate 10 percent higher than roads with a similar classification. Alternatively, a state may use crash rates resulting in fatalities and serious injuries.
- Use roadways with a crash frequency above a designated threshold, which eliminates the comparison calculation to other roadways.
- Define high-risk rural roadway characteristics that are correlated with specific severe crash types, such as cross-section width, lack of shoulders, substandard alignment, or a hazardous roadside.
- Use information gathered through means such as field reviews, safety assessments, road safety audits, and local knowledge and experience. Using information from observations in the field can identify high-risk locations that may not be identified through data analysis or roadway characteristics.

Other risk-based U.S. highway safety tools include the FHWA Crash Modification Factors Clearinghouse, which provides factors by which crash frequency may increase or decrease. Hundreds of factors are considered, including roadway geometry, pavement surfaces, adjacent land uses, delineation, lighting, shoulder treatments, and work zone conditions. Each represents a strategy that could be applied in a risk-based highway safety framework.

Safety Analyst is similar to Austroads' ANRAM software, but it does not explicitly emphasize risk.[90] It does appear, however, to perform similar analyses that equate to risk-based assessment of highway safety. Safety Analyst is a set of software tools to identify and manage a systematic program of site-specific improvements to enhance highway safety. The software automates procedures to conduct six steps:

1. Network screening
2. Diagnosis
3. Countermeasure selection
4. Economic appraisal
5. Priority ranking
6. Countermeasure evaluation

These six steps could be cross-walked to an ISO-like process. Safety Analyst's literature says it can be used to proactively identify sites with a high potential for safety improvement, which is an inverse way of stating it identifies high-risk sections or locations.

As these examples show, U.S. highway programs provide many examples of how agencies can illustrate their risk-based approach to highway safety.

Managing Risk from External Threats

More tools are becoming available to assist agencies with a risk-based approach to dealing with external threats, such as increased climatic and seismic events.

General Risk or Threat Assessments

The American Society of Mechanical Engineers Innovative Technologies Institute produced the *Risk Analysis and Management for Critical Asset Protection Plus* (RAMCAP) guide.[91,92] As its name implies, it is a process for assessing physical threats to physical assets. Sector-specific guidance has been developed for nuclear power plants, nuclear waste storage and transportation facilities, chemical manufacturing, petroleum refining, liquefied natural gas facilities, dams and locks, and water and waste water facilities. The RAMCAP guidance is intentionally generalized, so it can be applied to any sector.

The overall RAMCAP process is discussed here using the sector-specific guidance for water and wastewater management systems. The RAMCAP tool is described as a simple and efficient process to support consistent, quantitative risk analysis that allows for comparison of risks across different assets. The RAMCAP process can be applied to human-induced threats, such as terrorism and accidents, and naturally occurring threats, such as earthquakes and hurricanes. It does not address operational risk, or the risk of failure to achieve organizational objectives through process impediments.

The process describes seven steps that are similar to the ISO steps, but differ in that they are appropriate only to tangible physical assets and not intangible ones such as staff experience. It includes the following:

1. Asset characterization
2. Threat characterization
3. Consequence analysis
4. Vulnerability analysis
5. Threat analysis
6. Risk-resilience analysis
7. Risk-resilience management

The RAMCAP framework is relevant to managing threats to physical assets in that, as the seven steps show, it focuses on characterizing the assets by their traits, or criticality, and by the threats they could face. It differs from ISO and other frameworks in that it does not seek to identify opportunities. It does evaluate threats, and those that are low could be considered risks that are tolerated and not treated.

The RAMCAP framework does provides scales and values that could assist with objectively determining the benefits and costs of risk-reduction efforts. However, the user must provide key inputs, such as the assessment by law enforcement of the level of terrorist threat in a given area. This step requires subjective assessments based on the available expert guidance of the participating agencies.

The risk framework describes probability calculations that can be used to quantify risk

through the equation of R = T x V x C. R represents risk, T is threat probability, V is vulnerability, and C is consequence. It walks the user through an example of determining the probability of a terrorist attack on a specific water facility in a given year. The number of terrorist threats nationally is reduced to a localized probability that after several calculations of multiplying fractions by fractions results in a value between 0.0003675 and 0.0001045, which is the range of probabilities of a threat to a given facility in a given year. When that probability is multiplied by the assumed effects of the consequences, the benefits of a mitigation effort can be calculated. The cost of the mitigation can be divided by the benefits to reach a benefit-cost ratio. The user provides key values, such as the assumed economic costs of an attack on the water facility and the costs of various countermeasures.

Threats from earthquakes, floods, and other natural disasters can be estimated in the framework. It provides generalized probability tables, such as the likelihood of tornadoes or hurricanes at a given location in a given year. These can be used in calculating probabilities that can be multiplied by the consequences to determine risks to given assets. However, the risks are based on broad categories across entire regions of the country.

Climate Change Risks

A practitioner's guide to dealing with climate change in transportation includes a chapter on assessing the risk to and vulnerability of assets.[93] It reports that performing climate change risk assessments helps transportation agencies understand the consequences of climate change on infrastructure and supports decision making on prioritization and adaptation. It notes that climate-change risk analyses help agencies assess the uncertainty that climate change poses to their assets. The analysis can lead to improved short-term and long-term decision making, such as identifying which assets to harden first, how to incorporate long-term adaptation into the scoping of future projects, and identifying risk-mitigation strategies for existing and planned assets. It presents examples of incorporating climate change risks into agencies' processes, such as a California Department of Transportation (Caltrans) policy for evaluating new facilities during the design process for future sea level rise impacts. The report also captures a city of Toronto environmental assessment tool used in a public process to assess climate risks.

FHWA's *Climate Change and Extreme Weather Vulnerability Assessment Framework* is a guide for transportation agencies interested in assessing their vulnerability.[94] It gives an overview of steps for conducting vulnerability assessments and uses in-practice examples to demonstrate a variety of ways to gather and process information. The framework has three key steps: defining study objectives and scope, assessing vulnerability, and incorporating results into decision making.

The framework says climate change and extreme weather vulnerability are functions of a transportation asset's or system's sensitivity to climate effects, exposure to climate effects, and adaptive capacity. Tasks in the vulnerability assessment include gathering and integrating data and information on asset location, characteristics, and climate sensitivities; gathering and obtaining information on historical weather events and projected climate; combining the asset and climate information to identify vulnerabilities; and, potentially, assigning a level of risk of the climate impacts on the assets. The vulnerability assessment work is an iterative process; information gathered may inform climate information needs and vice

versa.

The framework includes risk assessment that considers the severity of a climatic impact with its probability. To consider its consequence on an asset or segment of the transportation network, the agency considers the risks, which are measured on the assets' degree of redundancy, the value of the asset, the effect of its closure, and other factors. These help assess the degree of consequence to an asset which, in turn, affects the degree to which the agency may tolerate, treat, or terminate the risk to the asset.

The framework includes a risk-register-like heat map of the consequence and probability of risks on assets or network segments. These risks are ranked on the degree of probability multiplied by the consequence to create a traditional risk matrix.

Although not an ISO framework, the framework parallels the ISO steps. Its early stages include establishing the context of what assets exist and what climatic variables may create risks. The framework moves through identifying which assets are at risk and analyzing what creates the risk. Treatment options are assessed and treatment steps identified, if possible. If risks cannot be treated, they are tolerated and monitored. Finally, communication with stakeholders and review and evaluation of changing risks occur on an ongoing basis.

The Federal Emergency Management Agency (2011) advocates what has been called an all-hazards approach that suggests planning for one kind of hazard or threat can increase an agency's or a community's ability to deal with others.[95] The generic framework for agencies preparing for a wide variety of risks has been dubbed the "three Rs:" redundancy, robustness, and resiliency.

The Committee on Climate Change and U.S. Transportation of the Transportation Research Board says integrating the extreme variability caused by climate change-driven weather events requires a new risk-based perspective from transportation planners and engineers.[96] They typically extrapolate from historical trends to forecast future needs and conditions that influence investment choices and operating plans. It warns that U.S. agencies may not be able to simply extrapolate from past weather patterns to predict the climatic risks they face in the future. It notes that floods are likely to be more severe, wind events more extreme, and droughts more common.

The committee notes that planning for the risks of extreme weather variability is not a future need, but a current one. The flooding caused by Hurricane Irene and Superstorm Sandy is likely to be repeated and represents one of the more common risks of climate change. It recommends as a risk-management strategy an inventory of at-risk assets so that they can be prioritized for treatment. The great cost of hardening these assets prompts the need for a risk-based approach to investment. Agencies will need enhanced skills in assessing risk to be able to make tradeoffs between the large numbers of assets that need to be hardened to withstand climate change.

The extreme events that in past years were considered to be outliers may become more common. The bell curve of weather events may well flatten with much more deviation from the traditional mean of events. Asset and risk managers need to establish as a basic goal for their programs considerations of extreme weather variability.

The Intergovernmental Panel on Climate Change (IPCC) notes that climate-change impact approaches are shifting from a disaster-response approach to a risk-management approach.[97] Risk-based approaches seek to build resistance to climate-induced impacts by making systems more robust and resilient. Risk management and climate adaption become linked as risk-based strategies to increase infrastructure's resilience also serve to mitigate the effect of severe climate events.

The difficulty in prioritizing all risk-response actions based on probabilities leads the IPCC to recommend that agencies consider a set of “no-regrets” mitigation steps to address climate change threats. These are steps or expenditures likely to produce both climate change mitigation benefits and other benefits, thereby warranting their investment even if severe events do not occur by a given planning horizon. For infrastructure, no-regrets investments could include the following:

- Updated design standards or design inputs that take greater storm frequency and severity into consideration
- Improved event forecasting systems, such as stream gauges and hydrological forecasting tools to better predict hydrological events and understand their effects on assets
- Increased inspection protocols to more promptly identify the effects of events on at-risk assets
- Coordination with land-use agencies to discourage development in vulnerable areas where impacts could exacerbate at-risk infrastructure
- Improved downscaling or localizing of climate change projections to better understand the likelihood of extreme events
- Improved asset inventory data, including more accurate elevations to understand more precisely the potential effects of flooding or storm surges
- The identification of at-risk slopes, routes, structures, and other assets
- Qualitative and simple probabilistic analyses to identify and prioritize storm event risks to assets

The lessons of Superstorm Sandy led New York’s NYS 2100 Commission to conclude that the state needs to develop a risk assessment of its infrastructure.[98] The commission says the state needs to identify assets that are vulnerable to extreme weather events, storm surge, sea level rise, and seismic events and prioritize future investment through the use of a lifeline network that defines critical facilities, corridors, systems, or routes that must remain functional during a crisis or be restored most rapidly.

It called for four general strategies to prepare for what it calls the “new normal” of more frequent extreme events. They are:

- Develop a risk assessment of the state’s infrastructure to identify assets that are vulnerable to extreme weather.
- Strengthen existing networks by improving the existing infrastructure with an emphasis on key bridges, roads, tunnels, transit, rail, and marine facilities.
- Strategically expand the transportation network to create redundancies.
- Build for a resilient future with enhanced guidelines, policies, and strategies so that new assets are constructed with more robustness or outside of vulnerable areas.

The Washington State Department of Transportation (WSDOT) provides a case study of an agency's risk-based assessment of its climate change impact.[99] It used FHWA's climate change risk assessment tool to evaluate the types of extreme weather events it is likely to experience and analyzed that weather's effect on vulnerable infrastructure. It noted that it did not consider its exercise to be a risk assessment because it used scenarios and did not assign probabilities to its impacts. However, the result of the analysis allows the agency to identify where its greatest vulnerabilities occur.

The agency says that like other risks it plans for such as retrofitting bridges against seismic risks, it plans to update its planning and design policies to protect its infrastructure from climate change. It says this risk-based planning is sensible asset management. The agency builds highways and bridges to last decades, so it must make them more resilient to have long service lives in an era of extreme weather.

The assessment included a downscaling exercise by university climatologists who took IPCC models and used them to predict the type of climate change extremes that could affect the state's climatically and geographically diverse regions. With these higher levels of precipitation, higher temperatures, and rising sea levels, the department conducted staff workshops to identify vulnerable assets. The agency made a point of including frontline maintenance personnel with first-hand knowledge of vulnerable assets, such as aging culverts. The workshops involved quantitative and qualitative assessments to identify through staff experience the agency's most at-risk assets.

Rock fall Hazard Programs

Rock fall hazard programs represent one of the most explicitly risk-based approaches to managing transportation assets. The steps in a rock fall rating and treatment program fairly closely parallel the steps in risk and asset management processes.

Most of the rock fall hazard programs derive from the Oregon Rockfall Hazard Rating System that was begun in 1984 and refined in 1991.[100] It still serves as a model for rock fall hazard systems and other types of risk-based analyses of assets.

It includes six main features:

1. A uniform inventory of slopes
2. A preliminary rating of the slopes
3. A detailed rating of the hazardous slopes
4. A preliminary design and cost estimate for the most serious sections
5. Project identification and development
6. Annual review and evaluation

The first two steps result in categorization of all slopes by an A, B, or C rating. Slopes in the A category are prioritized for further analysis, B slopes are analyzed as resources permit, and C slopes are deemed to be low risk and not included in the database or subject to further analysis.

An objective assessment is conducted on the A slopes by risk factors:

- Slope height
- Ditch effectiveness, which assesses its ability to prevent a falling rock from traversing the ditch and reaching the roadway
- Average vehicle risk, which is a measure of the percentage of time that vehicles are present in the rock fall zone
- Sight distance percentage, which determines the length of roadway a driver has to avoid a sudden hazard
- Roadway width, which is a function of a driver's maneuvering room
- Geologic character of the slope, which reflects its proclivity to fail or produce falling rocks
- Block or rock size prone to falling
- Presence of water or other climatic factors
- Rock fall history

The points assigned to each factor range from 3 to 81, which leads to substantial risk-assessment differences between the lowest- and highest-risk sites.

Oregon has refined and updated its process and other states have adapted it with additional criteria and data-collection methods. However, the original risk-assessment process is cited here to make the point that analogs for risk-based programs are long established, their concepts can be adapted to other assets, and their utility has been repeatedly validated. In the steps cited above, for example, "slopes" could be replaced with "culverts," "bridges," or "lifeline routes" and the steps would still be useful for a basic risk-based asset analysis.

In the early 1990s, WSDOT developed a risk-based programming application that includes a numerical rating system that relies on easily measured and quantifiable factors to evaluate the risk of an unstable slope impacting a highway.[101] This numerical rating system assigns points to 11 risk categories using an exponential scoring system that quickly distinguishes increasing hazard and risk potential. The rating system addresses the type and severity of a slope hazard in only one rating category, while the remaining categories are dedicated to establishing risk factors to the highway. Generally, the higher the total point value for an individual slope, the higher the overall risk to the highway. In addition to numerically rating the slopes, WSDOT conducts a cost-benefit analysis on potential projects that considers the anticipated cost of traffic impacts resulting from a slope failure with the annual maintenance costs over 20 years versus the cost of mitigating the slope hazard. To select slopes for programming, WSDOT initially concentrated on slopes along high-volume corridors with higher ratings, positive cost-benefit ratios, and higher average daily traffic (ADT). It has more recently moved on to slopes with lower ratings, positive cost-benefit ratios, and lower ADT. Since 1995, WSDOT has mitigated about 250 (8 percent) of its known (about 3,000) unstable slopes and about 35 percent of its highest-risk slopes at an approximate cost of $180 million.

Seismic Risk Assessment Approaches

Land and Thompson (2013) track the history of the bridge seismic retrofit program in California that somewhat follows the evolution of risk-based approaches.102 They noted that

65 years passed between the 1906 San Francisco earthquake and the 1971 San Fernando earthquake, the first major earthquake of the recent era. During those decades, little was done to protect bridges from seismic damage. As noted by Lam (2003) and others, as the consequences of failure increased in society, so did the emphasis on managing that failure. Land and Thompson noted that the 1971 event did not precipitate a major statewide retrofit program, but subsequent earthquakes in 1987 and 1989 convinced policy makers of the need for an aggressive bridge retrofit program. In an example of how a risk can create opportunity, the 1987 Whittier earthquake did not create extensive damage, but it provided the department with valuable lessons on bridge vulnerabilities and further convinced the public of the need for a retrofit program. The damaging 1989 Loma Prieta earthquake accelerated the legislative support for an aggressive retrofit program.

Caltrans engineers developed a risk-based process for prioritizing the state's 24,000 bridges. The objective was to prevent loss of life, not the more expensive objective of preventing all damage to bridges. The department's engineers developed a risk-based algorithm for three categories: site hazard, structure vulnerability, and system impact, as seen in Table 20. By applying the algorithm to all bridges, a risk-based prioritization was possible.

Table 20 Caltrans retrofit criteria.

Category/Characteristic	Characteristic Weight
Site Hazard	
Soil Conditions	33%
Peak rock acceleration	38%
Duration	29%
Structure Vulnerability	
Year Designed	25%
Outriggers or shared columns	22%
Abutment type	8%
Skewness	12%
Drop type failure	16.5%
Bent redundancy	16.5
System Impact	
Average Daily Traffic	28%
Lease air space residential	15%
Leased air space parking, storage	7%
ADT over/under structure	12%
Facility crossed	7%
Route type on bridge	7%
Detour length	14%
Critical utility	10%

In 2003, a state seismic advisory board issued a report recommending that the comprehensive, risk-based process continue with continuous-improvement and continuous-monitoring processes incorporated. The recommended steps included the following:

- The state should adopt as official policy Caltrans' policy of building, maintaining, and rehabilitating bridges to provide an acceptable level of earthquake safety.
- Caltrans should maintain its construction standards to provide safety and functionality of lifeline bridges and continue its practice of independent reviews to ensure compliance with those design standards.
- Caltrans should regularly reassess seismic performance to ensure that the design

standards are adequate as additional seismic events and research provide new information.
- Caltrans should continue its commitment to seismic research.
- Caltrans should maintain its rapid response capability to evaluate, repair, and restore damaged bridges.

Although the advisory board did not refer to the concept of resiliency, its recommendations incorporate the elements of a risk-based, continuously improving resiliency program for seismic retrofit of bridges.

WSDOT likewise developed an objective, risk-based process for prioritizing its seismic retrofit program.[103] The risk elements include the structural redundancy of a bridge, the seismicity of its location, the route recovery time, and ADT. The structural redundancy focused on each bridge's number of columns because non-redundant one-column bridges are at higher risk than structures with multiple columns. The seismicity was based on U.S. Geological Service maps, which rate the 1,000-year seismic risks of sites. State routes were given higher priority than local routes, and priority was given for structures carrying higher traffic volumes. With this criteria, the department could prioritize for retrofit its bridges facing the highest risks.

Bridge Scour Risks

Reference Guide for Applying Risk and Reliability-Based Approaches for Bridge Scour Protection, NCHRP Report 761, provides guidance for estimating threats to bridges caused by scouring.[104] This report presents information on identifying and evaluating the uncertainties associated with bridge scour prediction, including hydrologic, hydraulic, and model-equation uncertainty. It includes tables of probability values to estimate scour depth when a bridge meets certain criteria for hydrologic uncertainty, bridge size, and pier size. For complex foundation systems and channel conditions, it presents a step-by-step procedure to provide scour factors for site-specific conditions.

A Case Study of Balancing Investments in Assets and Preparing for External Threats

In 2013 there was a series of bushfires in Australia across the state of New South Wales, the worst of the fires beginning in the Greater Blue Mountains Area on 16 and 17 October 2013. High fuel loads, coupled with warm, dry and windy weather, provided dangerous conditions which fueled the fires. The fires were the worst in New South Wales since the 1960s. By 19 October 2013, 248 houses and other structures were destroyed across the state. Two fatalities were attributed to the fires. Insurance claims were estimated to exceed $94 million (AUD).

The Blue Mountains City Council (BMCC) had been reporting a growing problem for state of good repair for infrastructure and had already established a six-point strategy for financial sustainability with risk management as a central activity. The City was well prepared when disaster struck. The risk register had identified the risk of disaster recovery and had a plan

to meet the disaster. The asset and risk management plans had identified the risks associated with fire trails in poor condition and that additional funds were needed to improve fire protection zones. The City had a 10-year plan to manage all risk.

Since 2011, the city prepared asset and risk management plans using an international template system. The Asset Management Plans align with IIMM and ISO 55000. The Risk Management Plan aligns with ISO 31000.

The asset management strategy that was in place in 2013 connected the asset and risk management plans and set out a 10-year strategy to engage with the community to achieve a balanced trade-off between service levels, risks and what the community was prepared to pay. The clear communication of the 10-year strategy changed the reactive nature of resource allocation, driven by elected Councillors response to clear and present community need such as emergences and policy and funding programs by other levels of government.

The Council decided to take a 10-year strategic approach and communicate what a 10-year sustainable plan that managed risk looks like by using three scenarios that balanced revenues, service levels and risk.

In 2012 Blue Mountains City Council (BMCC) began a conversation with the community about what they were prepared to pay for the level of service they wanted. This resulted in the Council's 2013-2023 Resourcing Strategy which provided a 10-year plan for the trade-off between revenues, service levels and risks across all services.

Through the Resourcing Strategy, the Council has set out its delivery and financial capability over the next 10 years. The Strategy also outlines the Council's major resourcing challenges and the six key strategies proposed to address them.

The Asset Management Strategy sets out a 10-year plan with three scenarios to balance service levels, risks and funding. The current funding level scenarios include closing facilities to manage risk and ensure safety. Risk was systematically identified, managed and risk management actions known before a failure or disaster happens. The risk management plan clearly communicates the planned options to manage infrastructure in bad repair, including plans to limit operation, close facilities or dispose assets.

Clear and present emergencies such as fires, earthquakes and asset failures will always attract more attention than the less visible but much larger emerging risk that accompanies a growing proportion of infrastructure in bad repair.

BMCC engineers had been reporting large infrastructure backlog for years, but emergencies and other priorities always came first. The key missing action was that the growing risk of infrastructure in bad repair was not clearly communicated. This is now done.

The City is financially sustainable under all three funding level scenarios that were reported to the community, but if the community is not prepared to pay more, service levels would be adjusted in line with the adopted six-point plan. This is on ongoing process, with annual reviews of the asset and risk management plans to ensure alignment with the budget, emerging needs, community attitudes and risks. There is an ongoing knowledge management improvement plan that continually improves data, systems and processes to manage risk.

The customer satisfaction survey in 2014 indicated high levels of community satisfaction and was better than previous years despite the clear communication over a two-year peri-

od that current service levels could not be maintained without increasing revenues. The City clearly communicated that there is a 10-year plan that included ensuring value for money service delivery. The community expects that risk is identified, managed and communicated and a 2014 communication strategy including surveys, workshops and a mail out to all residents resulted in the majority of residents indicating they would pay more to maintain current service levels and manage risk.

Managing Risks to Financial Resources

An Internet search of the terms "risk management" and "asset management" turns up thousands of references to managing risks to financial resources or assets and far fewer references to managing risks to transportation assets or organizations. This imbalance reflects the much longer history and more robust frameworks for managing risk in the private financial sector. In fact, a majority of individuals who practice risk management view the discipline as managing risks to financial returns.[105,106,107] Many authors have produced detailed textbooks of hundreds of pages of algorithms to measure risks. The risks they refer to are risks that investments may suffer because of stock market volatility, commodity price changes, currency exchange rates, inflation, or political volatility affecting global markets. The financial world's management of risk reveals a rich, diverse, and highly quantified set of evaluation tools to measure risks to individual assets and across an entire portfolio.

Some emerging elements of risk management among transportation agencies are borrowing concepts from the financial world to develop aggregate measures of the amount of financial risk transportation agencies face. This section examines financial risk measures from the corporate world and describes how similar metrics are emerging to measure long-term risks to the financial sustainability of transportation agencies.

Fone and Young (2005) relate the precedent for managing risks in the financial sectors to the template that has spread to expectations for the public sector as well.[108] Now, the expectation is that the same diligence investment fund managers use be applied to managing the risks to government investments and operations. Both investment portfolios and performance-based government programs are expected to be managed to minimize risks to performance.

An example of how the financial trading industry's asset-risk management has translated to the public sector lies in the 10-year financial metrics included in Australian local government asset management financial plans.[109] The local governments in the states of Queensland, New South Wales, South Australia, and Victoria produce 10-year asset management plans that are accompanied by financial plans. The financial plans include metrics forecasting the degree of financial adequacy, or financial risk, the governments face. The risks are primarily that the value of their transportation assets will decline in the future because the agency is underinvesting or has such high debt levels that it will not be able to sustain infrastructure investments. These metrics are relatively simple compared to those produced on Wall Street. They include long-term debt ratios and forms of the asset sustainability ratio, which is a measure of whether the agency is investing as much in asset renewal as it experiences in asset depreciation. These examples allow an agency to illustrate the degree of financial risk it is accepting in terms of its long-term ability to invest enough to sustain asset

conditions. The sustainability ratios measure the degree of long-term risk and the degree to which the agency is meeting its intergenerational equity commitments. The asset portfolios that local governments manage are the highway and other infrastructure assets reported on their financial statements. The agencies are expected to sustain or grow their asset values over time so that they leave future users with a healthy and robust infrastructure network.

Another example in which overall risk levels are aggregated and reported is reflected in the U.S. Office of the Comptroller of the Currency's *Semiannual Risk Perspective*.[110] The June 25, 2014, report says that in aggregate, U.S. banks are taking on more credit risks after being more conservative after the 2008 financial crisis. The comptroller tracked the risk performance measures of U.S. banks and issued a caution that banks are easing credit standards and making riskier loans as a result of tightening competition. The report says banks are raising their risk appetite because of a sluggish economy and low interest rates. This caused the Office of the Comptroller to warn that banks are assuming greater risk and exposure to potential future losses. The report says the agency will focus on the banks' risk-management practices to ensure they are not taking on inordinate risks that could threaten the economy.

These examples illustrate a maturation of risk measurement from focusing on a single function or asset to an aggregated, system-level measurement of risks. The portfolio manager can assess across the entire portfolio whether risk levels are changing, whether they are acceptable, or whether investments need to be adjusted to stay within the fund's risk appetite. Similarly, the Australian local government's financial risk metrics allow the agency's decision makers to make strategic investment changes in asset classes by each of the upcoming 10 years to keep financial risk at an acceptable level. The Office of the Comptroller of the Currency can use risk-based financial performance measures to assess the overall degree of risk in the entire national banking system.

The state planning agencies in the Australian states use individual local sustainability metrics to make comprehensive, system-wide assessments of the overall financial risks to all local government assets.[111] This statewide assessment has some similarities to the U.S. Office of the Comptroller of the Currency's assessment of banks' loan portfolios. The annual state audit summaries produce tables, pie charts, and trend lines illustrating how financial and infrastructure management risks were changing year by year for local governments' assets. Like portfolio managers on Wall Street, state and local decision makers can understand if their financial risk levels are changing as a result of their investment decisions.

The MAP-21 requirement to develop financial plans to support transportation asset management plans may lead to more comprehensive financial analysis of the risk transportation agencies face in sustaining asset condition and performance. These plans are likely to include reports of the Asset Sustainability Index, which is a ratio of the long-term budget for asset investment divided by need. For instance, if an agency needs $100 million a year to sustain pavements but expects to have only $80 million a year, the ratio would be $80 million/$100, or 0.8. The lower the ratio, the greater the unmet need and the greater the financial risk the agency faces.

The U.S. Highway Trust fund was on the verge of insolvency in 2014, creating substantial

risk and uncertainty for agencies that depend on Federal-Aid Highway Program assistance. Predicting income risks is likely to become an increasing activity for state agency risk managers.

An example of how one state forecast its long-term financial uncertainty is the Vermont Agency of Transportation's Section 40 report to its legislature.[112] The report name refers to the state legislation section that required the report.

The report notes that Vermont faces three major long-term income risks. First, state fuel tax revenues are declining because of greater vehicular fuel efficiency, fewer miles traveled, and more reliance on other modes. Second, its forecasts the federal Highway Trust Fund will be level-funded at best, if not providing declining receipts. Third, it expects construction inflation to outpace income and lead to a reduction in real purchasing power of the revenue it does receive. These trends are exacerbated by increasing investment needs created by aging infrastructure that has not been maintained because of inadequate income. For the 2014–2018 period, the agency needs $698 million to meet its basic preservation and operations needs, but it has only $457 million. That leads to an approximate sustainability index of 0.65 percent for the period. The department did not forecast need beyond 2018, but it did forecast the erosion of some revenue streams out to 2033. It forecasted that traditional state fuel tax receipts will fall from $60 million in 2013 to $39.3 million by 2033 if fuel consumption continues to decline. That is offset with new fees and assessments, which will cause income to rise slightly in inflation-adjusted terms until 2021, then decline in real terms because of inflation. In inflation-adjusted dollars, the agency will have a budget in 2033 of about the same size as today. In other words, based on its best forecast it will have only two-thirds of its needed revenue for the next 20 years. This creates substantial risk of declines in asset condition and performance.

NYSDOT produced a similar forecast in its *Transportation Asset Management Plan*. It says its greatest overall risk is the uncertainty of Federal-Aid Highway Program funding, which comprises 70 percent of its construction program. The existing degree of underfunding and forecasted flat or declining overall revenue causes the department to calculate an Asset Sustainability Index of 0.3 for pavements and bridges for the next decade. In other words, it forecasts having only 30 percent of the needed funding to achieve and sustain its targeted bridge and pavement conditions. Federal uncertainty and overall low funding levels are significant risks for the agency's future asset conditions.

The MAP-21 requirement to develop transportation asset management plans will lead more states to generate fiscal forecasts and compare them to needed levels of investment to sustain asset conditions. This requirement mirrors in several ways the Australian requirement to estimate the degree of adequacy and risk in long-term fiscal forecasts for infrastructure. The requirement also could lead to the ability to estimate overall levels of financial risk facing states, regions, or even the nation as a whole. These developments appear to mirror an evolution in U.S. transportation agencies of managing financial portfolio risk somewhat similar to the way investment fund managers manage portfolio risk.

The New South Wales Treasury notes that integrating design, construction, operation, and maintenance over the life of an asset in a single project finance package can encourage maximum innovation from the private sector to improve the design and performance of

the infrastructure and reduce the whole-of-life costs.[113] It encourages public-private partnerships and design-build-operate-and-finance projects as a means to reduce the risk of higher costs and less efficient major projects.

However, Grad and Kenyon (2013) note that several high-profile Australian public-private partnerships failed because traffic revenues did not generate enough to retire the debt leading to default. That left investors, many of whom were local citizens, with substantial losses. They note that recriminations and class-action lawsuits resulted.[114] Ableson (2012) notes that these high-profile failures illustrate the substantial traffic-projection, income, and financing risks that can come with issuing debt for transportation projects.[115]

Managing Information and Decision Risks

Risks to information and decision making come in many forms. A key risk is created by a lack of information, such as when a transportation agency lacks data on critical assets such as drainage structures or curb ramps. If a major water quality regulation is enacted, the agency may not know its risks for bringing drainage structures into compliance. Similarly, a lack of data about where curb ramps are needed creates risks that the agency does not know the cost to comply with accessibility requirements.

Other risks relate to the quality of forecasts from models, such as pavement, bridge, or maintenance management models. Inventory data may be inaccurate or outdated, leading to problems not only with models, but also with understanding asset conditions, treatment needs, or even location.

Security of information systems is a major risk. Hacking, phishing, and other threats can expose sensitive personal or medical information or threaten the integrity of financial management systems.

Information risks, therefore, cover a broad area that can degrade decision making, investment quality, or the privacy and security of sensitive information and transactions.

General Information System Risks

Information risks take two general forms. The first is risks related to security and protecting data from malicious acts or degradation through poor processes, such as a lack of regular data updates. The second is risks related to data and information that do not meet users' needs, such as a lack of quality data for making performance-based decision.

The British National Technical Authority for Information Assurance says information is the currency of today's society, so government needs to identify and mitigate risks to good information.[116] It notes that information risk includes risk to information technology (IT) systems, but it is broader and can include risks to all information that supports decision making. Stressing the British approach that risk management is about balancing opportunities and threats, it notes that not providing information can create risks. Information risk management, therefore, is about reducing threats while creating opportunities to improve decision making for more stakeholders by providing data in secure and accurate ways. The

guide stresses that both processes and culture matter to managing information risks. Security firewalls and processes need to be in place, and management at all levels needs to be engaged to ensure that data and information are readily available to all decision makers inside and outside the organization.

It provides a checklist of 24 key questions in six areas:

- Have we assessed the importance of information to our business?
- Have we assessed our information risks?
- Do we have a plan for managing these risks?
- Do all staff understand their roles and responsibilities in managing these risks?
- Does the organization have the right skills and technical capabilities to manage these risks?
- Is management information embedded in business processes?

The U.S. Government Accountability Office (GAO, formerly the U.S. General Accounting Office) provides two guides to help federal managers implement ongoing information security risk assessment processes. It portrays data protection as a risk-management process.[117,118] Computerized systems provide valuable information opportunity and process streamlining that is enhanced by the interoperability of systems. However, the very scope and interoperability of the systems increase their risks. Hacking into one system can allow access to others, creating vulnerabilities from many sources. The GAO guides provide a framework for managing information system risks and case studies of best practices.

The GAO identifies critical success factors:

- Securing management support to ensure that risk assessments are taken seriously by lower levels of the organization
- Designating groups or individuals to oversee and guide the risk-assessment process
- Documenting procedures for conducting risk assessments and developing tools to standardize the process
- Calling on business and technical experts from a range of sources to better understand the criticality and sensitivity of data operations
- Holding business units and individuals accountable to emphasize the importance of the data risk assessment and reduction efforts
- Documenting results so decision makers can be held accountable and progress recorded

The Queensland, Australia, government produces an IT risk check list.[119] It identifies risks to information and information systems in the following forms:

- Hardware and software failures
- Malware
- Phishing threats in which harmless-looking email messages are sent to users that when accessed infect the system with malware
- Human errors in processing or using data
- Catastrophic threats, such as fires or hurricanes that can knock out a data center

It recommends a standard three-step process to reduce information or data risks: prevention, preparedness for risks, and recovery plans for when risks strike. Prevention includes

the use of firewalls, required passwords, data backups, and thorough training of IT staff and general users. Secure socket layer, or SSL, technology to encrypt transaction data is another common security tool. It recommends having a risk management and business continuity plan to formalize the agency's steps to protect data and restore it after an emergency. It provides an 18-point checklist of steps executives should require to reduce risks to IT systems.

The Data Governance Institute provides a web portal of voluminous information on data governance, or the best practices in acquiring, managing, securing, and providing data.[120] It categorizes sound data governance in six areas:

- Data governance policies give weight to other data risk management steps, such as the development of procedures for ensuring data quality, security, and access to decision makers.
- Data quality policies or procedures include checks and balances to ensure that data are accurate, frequently updated, and meet users' needs.
- Privacy, compliance, and security guidelines are another risk-reduction component. They typically come from senior management mandate and usually include policies, procedures, and specialized software and technologies to protect data and identify threats.
- Data architecture and integration practices include steps such as requiring consistent data definitions, efficient architectures for storing and sharing data, cross-functional attention to integration, and identification of stakeholders and their data needs.
- Data warehousing and business intelligence rules and procedures provide data in easy-to-access ways and reduce the risk from malicious attacks or degradation of data quality or accuracy.
- Data management alignment involves realizing and documenting the needs of different stakeholders. One group that collects data for a specific purpose may not recognize the needs of another group to use the data in different ways. Management alignment seeks to maximize the use of data and systems by all stakeholders.

Hall (2006) identified numerous data integrity challenges for a performance-based transportation program in the United States.[121] A survey of state respondents indicated major concerns about data quality, collection efficiency, access, and sharing. The respondents also expressed the need for improved analytic and modeling tools. Presenters at a workshop on the report reported numerous problems with accessing data for optimized decision making. They discussed how data were isolated in management system silos, thwarting efforts to synthesize information and optimize decisions. One presenter described how different systems produced different answers to the same query, which undermined executive confidence in the agency and its decisions. Several presenters described how different units collected and used data that were optimized for their function without regard for how the data could benefit other divisions.

Secrest and Schneweis (2011) provide a transportation data self-assessment guide to help agencies determine the degree to which their data processes may be at risk.[122] The unofficial guide, produced for AASHTO, was a first step that led to an ongoing process to develop

an official data self-assessment guide, not yet published. They say the components of data management include a focus on quality data, alignment with strategic goals, clear definitions, the ability to aggregate or separate data spatially, regular audits of data, adaptable data management plans, clear organizational roles, and mechanisms for security and privacy.

One standard for data government and maturity is Capability Maturity Model Integration®, originally developed by Carnegie-Mellon University and spun off to the CMMI Institute. A white paper on the institute's services notes that it helps agencies assess their data maturity on a five-level scale from basic performance to a sophisticated, optimized level five.

Since the Capability Maturity Model was published in the 1980s, many other organizations and associations have developed similar ones. The IBM Data Governance Council is a group incorporating 52 corporations and associations.[123] Its 2007 model builds on the original framework, which describes five phases of data governance maturity.

Level one is an unstable environment in which processes are ad hoc. Success relies on the competence of individuals rather than on proven processes. At level two, successes are repeatable, but processes may not be and there is risk of failure because of a lack of ingrained processes. At level three, the organization adopts a set of standards and processes. At level four, organizations set quantitative quality goals for processes and maintenance. At level five, quantitative process-improvement objectives are firmly established and are continually revised to reflect changing business objectives.

The IBM council expands the original five-level model into 11 categories for assessing the maturity of an IT organization to reduce its risks of data quality, security, and usability. The categories of maturity include the following:

1. The organizational data owners' awareness of their responsibilities to support the business decisions of the organization
2. The stewardship or quality control discipline for data asset enhancement, risk mitigation, and control
3. The policies to articulate the desired organizational behavior
4. The processes to create value with data by supporting good decisions
5. The data risk management and compliance to identify, qualify, quantify, avoid, mitigate, or transfer data risks
6. The security and privacy processes to mitigate risks and protect data assets
7. The data architecture or design and structure of the systems and applications to serve appropriate users
8. The data quality management to measure and improve the provision of quality data
9. The classification and metadata, or the terms for identifying and classifying categories of data
10. The information life cycle management for the collection, use, and eventual deletion of data
11. The audit and reporting functions to monitor and measure the value of data, risks, and effectiveness of governance

The Minnesota Department of Transportation's *2008 Data Business Plan* represents an ef-

fort to formalize the vision, objectives, and processes for managing data.[124] The report does not address managing information risk because it preceded the department's embrace of risk management. However, its conclusions document the plan's intention to reduce information and decision risks by the following:

- Infrastructure preservation recommendations set the stage for implementing an organizational approach to asset management and addressing critical transportation infrastructure data gaps and needs.
- Traveler safety recommendations cite the need for better data on local road characteristics and more enhanced safety data analysis tools.
- Mobility recommendations identify the need for research and resources to collect potentially new data to address increasing interest in multimodal accessibility, reliability, and person throughput questions.
- Financial data recommendations address the need for enhanced information on life-cycle costs, return on investments, and data for evaluating service delivery options.
- Business intelligence recommendations highlight the value of department-wide solutions for improving data availability, integration, and analytical capabilities.
- Enterprise architecture recommendations provide an opportunity to strategically look at how all information systems might fit together to reduce data redundancies and create operational efficiencies.
- Data governance recommendations lay out a comprehensive series of steps for clarifying data roles and responsibilities and for setting standards and policies to reduce redundancies and promote data quality and reliability. They recommend developing a data catalogue and a thorough assessment of department-wide information system architecture to identify opportunities for integration to reduce redundancies and promote efficiencies.
- Geographic information system recommendations set the stage for business process, data governance, and organizational changes to fully achieve desired objectives.

Likewise, the CDOT 2011 *Performance Data Business Plan* does not use explicit information risk reduction terminology, but it does reference the need to improve the department's data and processes to support enhanced decision making.[125] The objective of the project was to support enhanced decision making in nine key performance areas: number of fatalities, bridge conditions, pavement conditions, roadside conditions, snow and ice control, roadway congestion, on-time construction, on-budget construction, and strategic action implementation. The plan addresses data management methodologies to support the department's ability to make informed decisions on how best to achieve the targets for each measure.

Managing Risks to Models

Crouhy et al. (2006) identify as a major concern in the modern organization the risks to models and decision-support systems.[126] They compare the modern manager to a pilot who flies by instruments. If the computers and other navigational aids fail, the chance of catastrophe increases. Although models and technology can be risk-reducing tools, they also can

create complacency so that a model failure combined with a significant unplanned event create a higher risk of failure if the manager or pilot is overly reliant on the model.

They cite examples of the criticality of the accuracy of financial risk and return models that are analogous to pavement-design risks discussed by Haas et al., who note that a common reason for premature pavement failures is underestimation of truck loadings.[127] Crouhy et al. emphasize that data and models are major sources of focus for modern risk managers who are responsible for capital assets. Although they discuss model risk in terms of financial assets, the concept applies equally to models addressing assets such as pavements and bridges.

Managing Risks to Business Operations

This section discusses risks to internal, or "back shop," business functions, such as purchasing, contracting, inventory control, and employee health and safety. Twenty years ago, these would have been the functions on which risk management largely focused in a traditional corporation. Then, risk management was concerned with reducing insurance costs and business losses. Even today, risk management in retail is largely synonymous with reducing loss through theft. Although these areas are no longer the primary focus of enterprise risk management, they remain business areas that can be improved with a risk-management approach.

Traditional Risk Management

The state of North Dakota's *Risk Management Manual* reflects a traditional approach to managing risks to the state by managing insurance costs; insurance claims; reported losses through accidents or injuries; loss to vehicles, property, or equipment; contracts; and worker's compensation claims.[128] The manual says the state enacted the risk management program after a state Supreme Court decision eliminated the state's sovereign immunity. The court said the state, like individuals, could be held responsible for negligence of its agents and employees. Its mission statement says the intent is to protect the state's assets—people, property, and financial resources—so it can meet its obligations to its citizens. The guide says the state will evaluate risk treatment strategies to decide whether to tolerate, terminate, transfer, or reduce risks. Strategies to tolerate risk include not buying insurance if risks are low or accepting some deductibles to retain some risk. When it can transfer risk it will buy insurance, join insurance pools, or transfer risks to third parties such as contractors or suppliers.

Risks from Theft, Fraud, and Malfeasance

Semiannually, the Office of the Inspector General of the U.S. Department of Transportation (U.S. DOT) issues a report to Congress on its activities. The report for April to September 2013 comprises 122 pages on investigations into fraud, waste, and abuse or recommendations for process improvements and efficiencies. The report catalogs examples of process failures, fraud, and abuse that represent risks to U.S. transportation agencies and, ultimately, taxpayers.[129]

One example the report cites is a paving contractor charged with disadvantaged business enterprise (DBE) fraud on $87 million in federally funded paving contracts. An indictment alleged that for more than a decade the contractor fraudulently obtained contacts by falsely certifying that a DBE was performing the work. In another case in the report, a contractor was convicted of filing false tax returns, conspiracy, and wire fraud in relation to the DBE program. Another example is a state right-of-way employee convicted of accepting a $30,000 bribe to allow a fraudulent claim for relocation assistance by a landowner affected by a highway widening. Another company agreed to pay a $2.8 million settlement to resolve allegations it defrauded the DBE program. A 2009 report by the U.S. DOT inspector general said that in the preceding five years there had been 278 indictments, 235 convictions, 191 years of jail time, and $737 million in fines and restitution related to fraud in U.S.

DOT programs. These examples illustrate the rationale behind risk-management practices to control contracting fraud and abuse.

Barnett and Russell (2009) reported that fraud is more common than many agencies suspect. Common types of fraud involve bid rigging, in which companies conspire to raise prices on bids, product substitution, bribery, kickbacks, and filing of false claims.[130]

The GAO issued guidance on the elements of a well-designed fraud prevention system. It was intended for disaster-relief programs, but is applicable to other federal programs.[131] It says reducing the risk of fraud requires three essential elements: upfront preventive controls, detection and monitoring, and investigations and prosecutions. The GAO says upfront preventive controls can screen out the majority of fraud and are the most effective and efficient means to minimize fraud waste and abuse. The guidance confirms that upfront controls work best when they require validation of eligibility for payment. Training personnel in fraud prevention and awareness also is an integral component of risk reduction. Detection and monitoring can occur with data mining for suspicious patterns and setting up fraud hotlines and other reporting methods. Program integrity is enhanced by investigating cases of fraud. However, the cost of prosecution is so high that it strengthens the benefits of upfront controls to prevent fraud in the first place.

The Chartered Institute of Management Accountants produced a 2008 *Fraud Risk Management Guide to Good Practice*.[132] It reports that although no system can eliminate all fraud, a formal process built on proven techniques can be an effective risk management process. The guide discusses the key components of an antifraud strategy. It says that fraud risk ought to be a regular component of an organization's operational risk management. A fraud review considers whether other operational errors or events could be the result of fraud, such as overpayment to contractors or lost inventory. Risks such as false accounting or theft ought to be assumed as a possible operational risk in any organization. The guide also says that overall responsibility for internal controls should be at the highest levels of the organization. Although senior management should have strong teams of auditors and analysts devoted to detecting fraud or abuse, it should be up to corporate leadership to create a climate of ethical behavior, put controls in place, and actively pursue reported fraud or abuse. Whistle-blower programs and hotlines can be an effective means to augment formal auditing processes.

The guide also calls for a comprehensive system of internal controls and policies. These often include division of responsibilities and checks and balances to reduce risk. In such a system, an originator of a request for a good, service, or payment is segregated from the unit that negotiates price and quality of the good or service purchased. Best-value processes are in place and handled by other parties to ensure arm's length, best-value transactions. Purchases or payments are clearly documented, and the accounting arm ensures that costs and payments are in line with budgets and standards. Training, monitoring, and regular reviews of purchases and processes are routine. Other techniques include pre-employment screening of employees who will be in fiduciary positions, regular audits, and data mining of transactions to look for suspicious patterns.

A risk management tool for construction bidding is the collusion-detection module in the AASHTOWare Project BAMS/DSS software. It compiles years of bid tab data and includes

collusion-analysis modules. These look for patterns in bidding that could indicate collusion between contractors on bidding, subcontracting, and provision of construction materials.

The British Treasury's *Good Practice Guide to Tackling External Fraud* focuses on preventing fraud from third parties seeking payment or benefits to which they are not entitled.[133] It says that all British departments have a responsibility to develop antifraud policies and demonstrate effective prevention practices. It describes the many different types of fraud risk that agencies should address. These can include people acquiring benefits they are not eligible for, organizations claiming exemptions or special status when they are ineligible, people who evade taxes or payments, companies or individuals colluding to rig bids, those who substitute inferior products or services, and those guilty of theft of money or other assets.

The guide asks agencies to take a strategic and systematic approach to identifying the types of fraud they are at risk for and to take comprehensive steps to prevent, monitor, and prosecute if it occurs. Responsibility for tackling fraud starts at the top of the organization and should be seen as an enterprise risk managed by senior leadership. Similar to other guides, the guide says that prevention is more effective and economical than prosecution, so agencies should emphasize developing controls that signal that fraud should not be attempted because of the high risk of detection. Creating a culture that does not tolerate fraud or accept it as unavoidable is another senior management imperative. Training and awareness programs are essential components of an effective fraud-prevention effort. Senior leadership should regularly evaluate the strength of internal controls to ensure that complacency or routine have not eroded their effectiveness. An internal fraud investigation unit is essential, as are procedures to seek outside investigatory help. Evidence that investigations are common serves as an effective fraud deterrent. Along with investigations, the imposition of sanctions also reinforces perceptions of effective fraud controls.

Similar to the British guide, the Australian National Audit Office produced *Fraud Control in Australian Government Entities*.[134] It depicts effective fraud risk control as a multilayered and continuous system. It begins with strong leadership enacting sound policies and procedures. It enacts continuous prevention, detection, and response processes that are continually monitored for improvement.

The Australian guide complements an enterprise risk management approach. It parallels enterprise risk management's stratified but coordinated approach of addressing fraud at the enterprise, program, project, and activity level. At the top are clearly stated policies, procedures, and commitment by leadership. At every level of the organization, managers are expected to implement fraud prevention and detection processes. Central to the effective practice are key strategies for fraud prevention and detection.

These strategies can include the following:

- Rigorous and transparent bidding and procurement processes
- Screening of potential suppliers
- Segregation of duties throughout the planning, scoping, selection, and negotiation phases
- Regular reviews of suppliers' products or services
- Data mining of bidding and payment events

- Internal and external reporting mechanisms such as hotlines
- Internal audits of processes
- Audits of final payments to ensure compliance with bid or purchase specifications

The guide emphasizes that fraud prevention is the first and most effective line of defense. Employees at all levels must be trained, empowered, and held responsible for implementing fraud control. Feedback loops are needed so that employees understand the actions taken when fraud is reported, including when it results in no action.

For high-risk activities, the guide says agencies should consider rotating personnel through processes to ensure no group can consistently hide malfeasance or fraud. High-level screening may be required for staff, regular reviews or audits can be enacted, and independent confirmation can be required for the proper delivery of services or products.

The guide depicts fraud prevention and detection as a key corporate responsibility in an enterprise risk framework. It equates it in importance to managing security risks, business risks, and other enterprise risks. The guidelines require agencies to undergo a fraud risk management assessment at least every two years. The risk assessment is to be conducted in accordance with the AS 8001-2008 fraud and corruption control standards, which are the Australian versions of the ISO standards.

Controlling Risks to Inventory

In 1999, the GAO provided an inventory control guide for government agencies. It is based on the GAO's analysis of seven private sector companies that were leaders in inventory control.[135] The GAO says managing the acquisition, production, storage, and distribution of inventory is critical to controlling costs, operational efficiency, and mission readiness. Proper inventory accountability requires that detailed records of produced or acquired inventory be maintained and that this inventory be properly reported in the entity's financial management records and reports. For example, detailed asset records are necessary to help provide for the physical accountability of inventory and the efficiency and effectiveness of operations. Also, the cost of inventory items should be charged to operations during the period in which they are used. Physical controls and accountability reduce the risk of undetected theft and loss, unexpected shortages of critical items, and unnecessary purchases of items already on hand. These controls improve visibility and accountability over the inventory, which reduces risks to the continuation of operations, productivity, improper storage, or excess or obsolete stock.

The GAO found repeatedly that agencies lacked complete and reliable information for inventory, property, and equipment. Agencies could not account for all their assets, verify the existence of inventory, or substantiate the reported inventory and property. Failing to know where assets are increases the risks of theft, misuse, unnecessary storage costs, or inaccurate estimates of program costs.

The guide identifies key factors for achieving consistent and accurate control over physical inventory:

- Established accountability
- Written policies

- A formal inventory control approach
- Frequent counts
- Segregated duties for control
- Knowledgeable staff
- Adequate supervision
- Periodic spot counts
- Ensuring the completeness of counts
- Investigating discrepancies between counts of assets and inventory records
- Evaluating the results of physical counts and determining their effectiveness

Managing Employee Safety and Workers' Compensation

In the private sector, a company's management of employee health care claims can reduce the health care premiums the company and employees pay, so managing health care costs is a standard risk management activity. Generally, state agencies cannot control their health care costs individually because premiums are negotiated statewide. One exception is workers' compensation costs, which often are agency specific. A transportation agency that puts employees into a highway environment generally has higher premiums for workers' compensation than an agency that has only office-based employees. This gives transportation agencies an opportunity to manage workers' compensation risks. If an agency reduces its workers' compensation claims history, its future premiums can be reduced.

Efforts to reduce workplace injuries and lower insurance costs lend themselves to an ISO-like risk management approach. The effort begins with acknowledging the workplace environment, identifying risks to worker safety, and analyzing and treating those risks. Ongoing monitoring and communication are necessary to stay abreast of changing workplace conditions and to communicate regularly with workers about safety practices.

Workplace risks and their associated premiums generally are treated two ways: preventing injuries from occurring through sound workplace safety programs and training and speeding workers' recovery from injuries to get them back on the job. Unlike standard health care costs, the cost of medical treatment is often not the highest cost of the workers' compensation claim. Lost wages can be a significant part of a claim, particularly if a worker is off work for months or even years. Therefore, the more effectively an organization gets an injured worker treated, rehabilitated, and back on the job, the lower the long-term workers' compensation costs will be.

The American Occupational Therapy Association, Inc., recommends an effective transitional return-to-work strategy for its multiple benefits.[136] For the agency, it lowers long-term lost work costs. For the employee, it provides physical and important psychological benefits. The worker's therapy can be managed by an occupational therapist, who compares the worker's physical capabilities with the job duties. The therapist can suggest reduced or amended duties that complement the worker's condition and therapy. More important, the worker sees himself or herself as a competent, able individual on a path to return to a full life with normal routines and habits. Returning to work and contributing to the workplace reduce feelings of permanent disability and resignation to diminished capabilities. The benefits are recognized as being so significant that workers' compensation insurers will either

pay for the transitional therapy or reduce company premiums.

The North Dakota *Risk Management Manual* says statistics show that employees who are away from work for more than six months have only a 50 percent chance of ever returning to their jobs. If the lost time extends to one year, the chance falls to 10 percent. Such claims create major expenses for agency's workers' compensation premiums for many years.

The North Dakota workers' compensation risk management program includes many industry standard recommendations, such as having an effective safety policy and program to identify workplace risks and take steps to reduce them. Annual inspections of facilities for safety equipment and safe working conditions are required. Training programs are essential to train workers about job safety.

Active management of workers' claims is another key component. The agency strives to help workers navigate the medical and claims process so they get prompt treatment and do not face paperwork or approval delays. This assistance can speed treatment and therapy and prevent lingering injuries from increasing long-term disability. Active management also helps the worker regain health and return to transitional work faster.

The Queensland Department of Transport and Main Roads 2011 *Guide to Risk Management* reports on an aggressive program to reduce worker injuries, particularly in construction zones. This not only reduces insurance costs, but also protects the health and safety of its and contractors' employees. The steps include appointing champions to ensure compliance with safety procedures and guide the development and implementation of appropriate policies. In work zones, it has experimented with a robotic mannequin and vehicle-activated variable speed message signs to inform motorists if they are speeding, paging units to notify workers if equipment has breached a predetermined work area, and reversing cameras on heavy equipment to improve operators' rear vision. The department also tracks workplace injuries as a core performance measure. Its reports injuries and lost time of employees as a key performance measure in its annual report.

The Public Entity Risk Institute (PERI) lists several key strategies for managing workers' compensation risks. First is reducing injuries, the holy grail of public sector workers' compensation programs.[137] Next is increasing the efficiency of the claims process by streamlining and automating processes. This also speeds a worker's receipt of treatment. Transitional return-to-work programs are emphasized. It is cheaper to have a worker performing part-time work at full-time pay than to have higher insurance premiums for many years. Reducing litigation by working cooperatively with injured workers can dramatically reduce costs. PERI estimates that in some states up to 50 percent of all benefit claims are litigated. Another strategy is to improve the quality of care for injured workers and ensure they see specialists and therapists as soon as possible. This speeds their recovery, improves their attitude toward their employer, and assists with their return to work.

Managing Risks to Programs and Projects

Project and program management are among the most mature and broadly documented areas of risk management in the U.S. transportation sector. This extensive body of literature reflects the large number of projects pursued by transportation agencies and their experiences with the negative consequences of risks to project cost, scope, schedule, and quality. This section examines several examples of risk management resources on program and project management. Three of the most comprehensive program and project management frameworks were already mentioned—the Project Management Institute standards for portfolio, program, and project management. The following sources illustrate guides on project management. When the project management is aggregated, it becomes a form of program management.

Guidebook on Risk Analysis and Management Practices to Control Project Costs

Guidebook on Risk Analysis and Management Practices to Control Project Costs, *NCHRP Report 658,* provides a comprehensive look at risk-related analysis tools and management practices for estimating and controlling transportation project costs.[138] The guidebook addresses the inconsistent application of contingency to risk management and cost estimation; lack of uniformity in methods of documenting and tracking risk in a comprehensive cost-control strategy or program; insufficient procedures for determining timing of risk management in various phases of project development; the need for matching appropriate tools to different project scales; insufficient organizational structure; organizational commitment, performance measurement, and accountability in transportation agencies; policy and political issues; and the regulatory environment. Although focused on project cost estimating, the guide illustrates the universality of the steps involved in risk management. It proposes a framework for estimating built on the commonly used steps of risk identification, assessment, mitigation, allocation, and monitoring. It notes that a lack of risk management can lead to cost overruns and loss of agency credibility. Highway construction can face many uncertainties, but a thorough risk-management protocol can help an agency manage the risks and exploit the opportunities created by uncertainties. It says that a process that directly addresses uncertainty and risk is the core of a comprehensive risk-management program. However, risk management should be viewed as a comprehensive management process, not just a tool of cost estimating. It stresses that risk management is cyclical and repetitive, involving continuous learning from past estimates and improving on accuracy. The goal is not to eliminate all risks, but to initiate the appropriate management responses to the inevitable risks that are identified.

Caltrans Project Risk Management Handbook

"Threats and opportunities" is the subtitle of the 2013 Caltrans *Project Risk Management Handbook*.[139] It intends to aid in the effective management of risks, both threats and opportunities. It says that risk management goes further than planning and that risk management needs to be executed effectively and monitored closely. It defines project risk as an uncertain event or condition that, if it occurs, has a positive or negative effect on at least

one project objective. It defines risk management as the systematic process of planning, identifying, analyzing, responding to, and monitoring project risks. It helps the project manager maximize the probability of positive events and minimize the probability and consequences of adverse ones. It is most effective when performed early in the life of a project and carried through its life cycle. As other authors have noted, risk management improves decision making. By identifying likely risks, the project manager can evaluate alternative approaches that can reduce risk and capitalize on opportunities. Risk management allows minimization of impacts, maximizing of opportunity, and reduction of management by crisis.

The handbook describes openness and transparency as a key success factor for risk management. It should promote an atmosphere in which risks can be freely discussed by anyone in the process, regardless of his or her place in the organizational hierarchy. Like other frameworks, it emphasizes a cyclical process that begins with planning, moves through risk identification and analysis, and proceeds through continuous monitoring. It emphasizes not only identification of threats, but also opportunities and triggers. Triggers are symptoms and warning signs that indicate whether a risk is becoming a near-certain event. It also notes that addressing one risk can create another. Hiring specialized services to address a high-risk task creates the risk of expensive or ineffective consultant management. Teams should be aware not only of the primary risks, but also residual risks, secondary risks, and risk interactions. When a risk is identified, the project team can decide whether to avoid it, transfer it, mitigate it, or accept it. Likewise, when opportunities are found they can be exploited, shared, or enhanced.

Project Risk Management Guidance for WSDOT Projects

The 2013 *Project Risk Management Guidance for WSDOT Projects* from the Washington State Department of Transportation provides a comprehensive framework for deploying risk-management strategies for construction projects.[140] Although focused on construction projects, the guide easily could be modified to address risks of almost any type. It lays out a series of steps and tools that could be modified for most risk management topic areas. The guide defines risk and explains the role of risk management in controlling uncertainty, maximizing likelihood of success, preserving value, and complying with policy. It goes into more detail than many other documents.

The guide provides step-by-step activities for risk management planning meetings as the team begins the process of identifying, mitigating, and monitoring project risks. It notes that much of the risk identification is conducted qualitatively, often relying on the judgment and discernment of veteran staff. Although probability-based tools can be used, their assumptions rely on the experience of the past practitioners. The steps described in the manual are similar to those described in the ISO guidance and elsewhere. The risk analysis begins with planning, followed by risk identification, qualitative risk assessment, and quantified risk assessment, if possible. It proceeds to risk response and concludes with risk monitoring and control. The guide provides spreadsheet templates for staff to follow and a template for a risk management plan.

Guide for Managing Risk on Rapid Renewal Projects

The second Strategic Highway Research Program (SHRP 2) produced a *Guide for the Process of Managing Risks on Rapid Renewal Projects*.[141] It notes that traditional risk assessment activities often lack rigor and formality in project planning, design, and delivery. This can be a particularly serious shortcoming on rapid renewal projects that emphasize a "get in, get out, and stay out" approach. These rapid renewal projects pursue accelerated schedules that increase the risk that unforeseen issues can create delays that lead to missed milestones, disputes over acceleration incentives, and disappointment by the public when construction dates are missed.

The guide helps managers quantify risks and provides guidance on the level of risk management needed. It provides a formal risk management process that addresses the accelerated schedule issues that confront rapid renewal projects. It provides performance measures, project delivery methods, and construction methods that complement rapid renewal projects. The guide provides a risk analysis process that allows a user to factor in issues such as project scope, strategy, and conditions to identify, analyze, treat, and monitor risks. The project also provides spreadsheets and a two-day training course.

Managing Risks on Complex Projects

The SHRP 2 *Project Management Strategies for Complex Projects* identifies a five-dimension framework intended to manage complex projects, including their risks.[142] Although not specifically a risk management guide, it is a project-management guide that emphasizes project controls that, in effect, manage risks. It says that complex projects are characterized by a degree of disarray, instability, evolving decision making, nonlinear processes, and dynamic processes with a high degree of uncertainty. The guide says that most project-management frameworks address three components: cost, schedule, and quality. The guide adds context and financing as sources of risk or uncertainty. Context risks include those caused by stakeholder expectations, local issues, environmental issues, or unexpected occurrences. Financing risks can be caused by uncertain public finances, bonding risks, tolling or other revenue risks, and public-private finance risks that occur on tax-increment financing or franchising projects.

The guide provides a process to identify and map risks or issues. It does not follow an ISO framework, but is similar in its risk-identification and analysis steps. The guide describes the steps of assembling a risk-identification team, brainstorming risks, developing ranking and mitigation for the risks, assigning resources to mitigate the risks, and integrating the risk-mitigation decision into the cost estimates, schedules, designs, and monitoring plans. It cites as an example a Mississippi River bridge project between St. Louis and East St. Louis, in which the project team reviewed the risk management plan weekly to keep abreast of issues.

Chapter 10: Critical Review of the State of the Practice and Case Studies

Summary

This chapter contains a critical review of the enterprise risk management state of the practice. It summarizes enterprise risk management in the U.S. corporate sector and in U.S. transportation agencies. Selected Australian examples are provided, as well. The conclusion is that the application of enterprise risk management is just emerging among U.S. transportation agencies, while it is more advanced in the corporate sector and among Australian transportation agencies. In the corporate world, risk management is an essential practice closely aligned with financial management, strategic planning, and due diligence. In Australia, it is a basic business practice expected of State and local governments. In the U.S., with few exceptions, agencies are only recently becoming exposed to enterprise risk management.

State of the Practice

Emerging and evolving are the best descriptions of the state of the practice for U.S. transportation agencies' use of enterprise risk management. Although agency officials informally manage risks constantly there are few examples of formal, documented enterprise risk management among U.S. transportation agencies.

The state of the practice differs in the corporate world. For publicly traded companies (those that sell their stock to the public) enterprise risk management is common. Active programs to manage risks are required by the Sarbanes-Oxley Act and federal regulations. The logic is two-fold. First, reckless corporate behavior imperils investors, many of whom are pension funds. Losses such as at WorldComm or Lehman Brothers hurts honest investors who must rely on the annual reports and other company disclosures to evaluate investment opportunities. Second, some companies are "too big to fail" and require government bail-outs to avoid damaging the entire economy if they were to collapse. The failure of WorldComm and Enron in the 1990s led to the Sarbanes-Oxley Act that makes risk management required in the corporate world. For banks, risk management also is standard practice and a regulatory requirement. Because bank deposits are federally insured, the federal government maintains an interest in ensuring that bad loans don't endanger depositors' assets.

Insurance companies represent the most traditional users of risk management. In fact, managing risks is their business. Any discussion of risk management in the corporate world should note that the originators and most active users of risk management are insurance companies. They are not, however, the subject of this analysis on enterprise risk management.

Corporate Sector Summary

As will be noted below, two studies by the National Cooperative Highway Research Program (NCHRP) found that ERM is not widespread among U.S. transportation agencies. There are no TRB nor AASHTO risk management committees and few risk management publications, other than ones relating to project risk management and highway safety.

In contrast, the corporate focus on enterprise risk management is evident in professional publications, and regulations governing public corporations. While the practice of modern insurance can be traced to the founding of Lloyds of London in a coffee house in 1688, the adoption of risk management in the rest of the corporate world became widely recognized by the 1980s and 1990s.

As early as 1952, Harry Markowitz of the Rand Corporation theorized about the inclusion of risk into investment portfolio decisions. [143] To oversimplify his premise, two investments may offer the same rate of return but one may have more "risk" as demonstrated by the variance in its expected return. For example, one investment may consistently provide a 5 percent return 95 percent of the time based on its history. Another provides a 5 percent return 80 percent of the time. If possible, the investor would accept the investment with the 95 percent probability of a 5 percent return over the one with a track record of providing a 5 percent return 80 percent of the time. For two investments without extensive histories, the risk or uncertainty surrounding them would be estimated. The concepts pioneered by Markowitz spawned an entire discipline of portfolio management that remains central to investments today. [144] Markowitz's original concept evolved to complex quantified risk-based investment theories that fill thousands of pages of graduate-level risk-analysis textbooks. [145] [146] These theories also are applied constantly by corporate investment analysts.

From Financial to Enterprise Risk Management

Expanding from the highly quantified field of financial risk management, enterprise risk management began emerging in the corporate world in the 1990s. The evolution is evident in the professional business journals. In 1994, one prominent article [147] defined a framework for risk management centered around risk-reducing investment instruments such as hedges and derivatives. However, by 1996, the Harvard Business Review published an article entitled, *"The New Religion of Risk Management"* [148] that cautioned against over-reliance on quantified analysis. It contended that many risks facing executives are new, and have no historical precedence that can be modeled accurately.

By the 1990s, corporations had survived the oil shocks of the 1970s, the oil price collapse in the 1980s, the October 1987 stock market plunge, and the historically unprecedented interest rates of the 1970s and early 1980s. Few of those shocks were predictable based upon past historic events. As already mentioned, the collapse of Enron and WorldComm because of poor investments and falsified accounting contributed to the wider adoption of enterprise risk management. ERM can be differentiated from financial risk management by two major elements. It tends be less quantified, as it often attempts to manage the unpredictable. Secondly, it is applied to areas such as corporate reputation, market share, customer and environmental safety, ethics and accounting, and other issues that could affect the company's profitability or investors' returns.

An anecdote cited in several risk management articles [149], [150]. [151], [152] relates to the 2010 BP oil disaster in the Gulf of Mexico. The articles noted that BP had an extensive risk management program focused on reducing the likelihood of past accidents. Extensive rules governed workplace safety, and even required employees to have lids on cups when walking with hot coffee. Analysis of past employee injuries provided probability-based results of how employee injuries could be reduced in the future. However, the risk program failed to anticipate the historic fire and spill that contaminated much of the Gulf of Mexico and killed 11 people.

The unpredictable nature of such events reinforced calls in the professional journals for broader-based enterprise risk management programs that expand beyond the traditional focus on workplace safety, financial risks, and regulatory compliance. One framework identifies three types of risks, each with a different management approach. [153] First are preventable risks, such as theft or failure to adhere to rules. These are best managed through compliance reviews. Second are strategic risks, such as selecting a poor-performing investment. These are best addressed by reducing the probability of a negative outcome. The third are external risks, such as political, natural, or economic disasters. These can be addressed through contingency planning and prompt mitigation responses.

A survey of 271 risk and financial executives in North America and Canada indicated that enterprise risk management was a corporate focus by 2006 but still was not uniformly implemented. [154] The benefits that executives reported were better-informed decisions, greater management consensus, increased management accountability, and smoother governance practices. By the mid-2000s, the chief risk officer and the risk function were becoming a critical part of the corporate business model. [155] Boards of directors, particularly in banking and financial companies, were taking active roles in overseeing the risk management efforts. [156]

Further regulatory requirements advanced the scope of enterprise risk management. The New York Stock Exchange (NYSE) required in 2004 its listed companies to have an independent audit committee that, among other duties, reviews at least annually the corporation's risk management process. [157]

In 2009, the U.S. Securities and Exchange Commission approved rules requiring a publicly traded corporation's board of directors to disclose its role in the corporation's risk oversight. [158] The boards specifically are to disclose whether the firm's compensation policies incentivize employees to engage in risk practices that threaten shareholder value.

The Federal Financial Reporting Act of 2010 was passed in the wake of the 2008 financial crisis. It required that companies such as banks and other financial institutions that are governed by the Federal Reserve to have active risk management committees reporting directly to the board of directors.

Reflecting the changing nature of risks, the SEC in 2011 issued guidance to publicly traded companies on how to disclose the adequacy, or lack of adequacy, of their risk practices to reduce cyber-attacks. [159] The SEC noted the substantial impact that security breaches can have on a firm's financial performance. Its guidance says firms should disclose to investors the probability of cyber-attacks upon the firm's financial performance.

In 2012 the credit-rating agency Standard & Poor's included as a new credit-worthiness factor the comprehensiveness of a firm's enterprise risk management program. If a corpora-

tion issues bonds, S&P rates the credit worthiness of the firm. The 2012 S&P change brought the firm's ERM program into the credit analysis along with other factors such as the firm's financial health. [160] Among the factors that S&P evaluates are whether management has successfully instituted comprehensive policies to identify, monitor, select and mitigate risks. It also checks if management has articulated risk tolerances to key stakeholders.

The Committee on Sponsoring Organizations of the Treadway Commission (COSO) is the risk-management professional organization for accounting and other financial firms. It reports that another emerging trend is for corporations to develop key risk indicators (KRIs.) [161] These differ from key performance indicators because performance indicators tend to be backward-looking or lagging indicators. COSO reports that emerging in the field of enterprise risk management is for corporations to develop KRIs to provide advance warning of changing risk profiles. It provides an example of a restaurant chain that monitors trends in disposable family income. It knows that patronage of restaurants represents a discretionary purchase that is influenced by the amount of disposable income families have. By monitoring national or regional trends in disposable household income the restaurant chain can identify if a key risk to its business plan is developing. Another KRI for mid-range priced restaurants is gasoline prices. As fuel prices increase, family disposable income declines and so does restaurant patronage. COSO reports that such leading indicators are growing in importance as risk managers seek to predict changes in their company's risk profile, and not just react to current risks.

At least one study links firms' profitability with the comprehensiveness of its enterprise risk management practices. [162] The authors used the S&P ratings of firms' ERM performance as a surrogate for the extent of corporations' risk management practices. It then correlated the profitability of firms rated by S&P. The rating agency categorized firms in groups of 1, 2, or 3 with each category representing a "weak," "adequate" or "strong" ERM rating. The researchers found a positive correlation between a firm's profitability and the strength of its ERM rating.

Risk Management Embedded in Corporate Practice

Another survey of corporate board members indicated that strategic risks are a greater concern than traditional financial risks. [163] As mentioned earlier, financial risk management originally was the focus of much of the corporate world's risk-mitigation efforts. However, in this study respondents saw ERM as a strategic rather than a compliance or financial issue. The sentiments in this survey reflect the recognition that external events and threats can have a major impact on firms' success.

This shifting of risk management to a broader, more strategic focus that encompasses the universe of potential risks facing corporations is evident in a review of the annual reports of randomly selected U.S. corporations. Risk considerations permeate these annual reports, reflecting the prominent role that risk management now plays in U.S. corporations.

A review of the annual reports of five of the nation's largest corporations illustrate how they are comprehensively managing risks, and reporting that management to their shareholders. Five of the 30 companies that comprise the Dow Jones Industrial Average on the New York Stock Exchange were selected at random and their annual reports to sharehold-

ers were examined. The five are Chevron, IBM, Johnson & Johnson, Caterpillar, and Home Depot. This review illustrates how widespread are the risk management practices in major publicly traded corporations, and how they emphasize strategic risks, and no longer only financial ones.

Typical of the other reports, Chevron early in its annual report notes that all of its forecasts for the upcoming year are subject to risks. [164] It and the other corporations say shareholders should understand they makes good faith efforts based upon current expectations but they cannot guarantee the expected outcomes. Chevron lists a number of risks that could influence its results including:

- Changing crude oil and natural gas prices;
- Changing refining, marketing and chemical profit margins;
- The actions of competitors or regulators;
- Timing of exploration expenses;
- The competitiveness of alternative-energy products;
- Technological developments;
- The success of partners;
- The potential failure for wells to produce as expected;
- Potential start-up delays;
- The effect of wars and other unpredictable events;
- The actions of the Organization of Petroleum Exporting Countries (OPEC);
- Potential liability for environmental issues;
- Environmental regulation;
- Litigation;
- Unexpected government actions, not only in the U.S. but internationally;
- Foreign currency valuation changes, or;
- Changes in accounting rules.

Chevron advises in the annual report that it operates globally from Angola to Vietnam. Internal governmental and external political, economic or even military events can influence its operations. It includes a section on risk factors in its annual SEC 10-K filing that is a supplement to the annual report. It elaborates on additional risks that could affect the company's profitability including:

- Changing commodity prices – As a commodity business, it is greatly affected by changes in the international price for oil and natural gas;
- Successful exploration – It notes that its continued success relies on continually finding new energy sources;
- Natural and human factors – It operates both in dense urban areas but also in difficult-to-access remote ones. Operations can be affected by human factors such as political unrest but also by natural events such as floods and seismic activity.
- Inherent risks – Chevron's results depend upon its ability to identify and mitigate the risks and hazards inherent in operating in the crude oil and natural gas industry. It says it utilizes a comprehensive risk management system to build and operate its facilities safely but that physical risks such as explosions and leaks are inherent.

- Liability risks – The company daily produces, transports, refines and markets material with potential toxicity. This exposes the company to legal and liability risk through government penalty or civil action.
- Uninsurable losses – The company does not insure against all losses exposing the company to substantial financial risk.
- Political instability – The company's exploration and production operations can be affected by changing political and regulatory changes in any of the many countries in which it operates.
- Regulation of greenhouse gas emissions – Continued public, political or economic actions to regulate greenhouse emissions could affect the corporation.

Chevron reports it also is exposed to many market risks such as changing interest rates, or currency prices, in addition to oil-market volatility. The company's market exposure is monitored daily by an internal Risk Control group in accordance with its risk management policies that are reviewed by the Audit Committee of the Board of Directors. The company also tracks credit risk, which is the risk that a customer will not pay. It says it distributes it sales broadly reducing the risk that one large customer's failure to pay will materially affect revenues.

It also reports the risks that its investments of pension assets will be adequate to meet the pension obligations of its employees. It reports upon its expected pension fund investment return, as well as upon the expected growth in future medical obligations to pensioners.

Chevron reports that five groups provide risk oversight. [165] The board of directors monitors overall corporate performance, financial compliance and the effectiveness of its enterprise risk management. This includes oversight of risk management systems, review of facilities and operational risk, portfolio review, and geopolitical risk review. It receives reports from numerous centers of enterprise-level risk management including strategic planning, legal, health, safety and environmental, technology, security, finance and global exploration.

The Audit Committee assists the board in oversight of financial risk exposure and compliance risks. The Board Nominating and Governance Committee assists with risks associated with the company's oversight structure. The Management Compensation Committee reviews risks relating to how executives are compensated and assists with succession planning. The Public Policy Committee assists with risks connected with the social, political, environmental, human rights or public policy aspect of the business. It also assists with tracking risks from regulatory or legal changes.

The other corporations examined used similar formats for reporting risks, but the risks vary by their industry. IBM reported to its shareholders in 2014 many risks including one particularly important to its industry, cyber risks. [166] It infers that cyber security is both a threat and an opportunity. Concern over cyber security by other firms provides a market for IBM's security products. At the same time, it creates risk to its own operations. It mitigates those risks through managing its own data, performing on-going risk assessments, and training employees to foster a culture of security.

It reports that in the current environment there are numerous and evolving risks to cyber security and privacy, including criminal hackers, state-sponsored intrusions, industrial espionage, employee malfeasance, and human or technological error. Computer hackers and others routinely attempt to breach the security of technology products, services, and sys-

tems, and those of customers, third-party contractors and vendors. Such breaches could result in unauthorized disclosure or destruction of company, customer, or other third-party data, theft of sensitive or confidential data, system disruptions, and denial of service. The company, its customers or third parties could be exposed to financial loss, liability or regulatory action. In addition, the cost and operational consequences of responding to breaches would be significant.

Another risk common in the information industry is a loss of skilled personnel. The competitive salaries in the technology field can lead to loss of personnel to competitors. Another risk facing IBM that is not common to Chevron is IBM's exposure to government budgetary issues because of its large number of government-support contracts. If State or Federal budgets are reduced or political changes occur, it could affect company revenues.

The Johnson & Johnson Corporation that produces health care products faces risks unique to its market niche. [167] These include:

- challenges inherent in new product development, including obtaining regulatory approvals;
- uncertainty of commercial success of new and existing products;
- significant adverse litigation or government action, including related to product liability claims;
- changes to laws and regulations and global health care reforms;
- trends toward health care cost containment;
- increased scrutiny of the health care industry by government agencies;
- financial instability of international economies;
- complex global supply chains with increasing regulatory requirements;
- product efficacy or safety concerns resulting in product recalls or regulatory action.

As with Chevron and IBM, references to risk appear dozens of time in the Johnson & Johnson annual report. Challenges to its company's patents pose a particular risk. Such a challenge could not only affect future earnings but also require payment of past damages. Another risk is the impact of patent expirations. As the company's patents expire, competitors may be able to legally produce and market similar products or technologies.

Health care and insurance changes in the U.S. and abroad pose another set of risks. Another risk is that competitors reach the market first with new products. Potential product liability and questions about the efficacy of products that result in recalls and litigation is a particular risk for a pharmaceutical company and one that is cited in its annual reports. Hacking, cyber security, and the theft of trade secrets also present a risk.

Johnson & Johnson reports having a comprehensive and multi-layered enterprise risk management program. [168] It discloses that its enterprise risk management framework allows it to:

- Identify potential events that may affect the entity;
- Manage the associated risks and opportunities, and;
- Provide reasonable assurance that the company's stated objectives will be achieved.

It reports that its board of directors meets regularly with key risk managers including strat-

egy, compliance, reporting and operations managers. On a secondary level, it reports having risk analysis processes related to regulatory compliance, health care compliance, reputational risk, financial risk, operational risks, and an informal process for assessing climate change risks.

With health care compliance being particularly relevant, it reports having a comprehensive risk-assessment scan methodology to assess risk to health care compliance, the Foreign Corrupt Practices Act, government contracting, and privacy. The scan methodology identifies risks and measures the risk exposure. A proprietary database contains current information on risks and risk mitigation and reduction programs. It says it also conducts face-to-face reviews to assess risks and take mitigation actions.

Caterpillar reports another set of risks because of its market sector, which is producing heavy construction equipment. Its corporate risk disclosures [169] advises investors that its market is particularly sensitive to global economic downturns. Its market is cyclical and affected by high unemployment, low consumer spending, lower corporate earnings and low levels of government and business investment. A change in any of these could be a key risk indicator that foreshadows a sales downturn, or could represent pending sales increases.

Its customers are disproportionately in the energy, mining and constructions sectors. Declines in commodities prices can depress demand in the energy and mining sectors. Prices in those industries are frequently volatile and affect Caterpillar sales. Rates of infrastructure spending also play a key role. As government and private sector infrastructure spending sector changes, so does the sale of heavy construction equipment.

Currency fluctuations are a particular risk because many of its sales are abroad. The company is paid with foreign currency that can lose value against the dollar. International interest rate changes also affect the company more so than other corporations. As interest rates rise, borrowing becomes more expensive and commercial construction activity softens. Interest rates also affect equipment sales because a division of Caterpillar finances equipment purchases. As rates rise, it must charge more interest which raises the cost of financing a purchase. International economic trends, such as a decline in the large amounts of Chinese investment seen in recent years, pose a disproportionate risk to Caterpillar.

Caterpillar's ERM efforts extend beyond compliance and is an integrated part of its strategic planning. [170] An executive equated its ERM to a "strategic conversation" with all business units about what could affect corporate objectives.

Caterpillar incorporates risk assessment and discussion of mitigation plans into formal strategic planning activities and communications with the board's audit committee. Business-level assessments take place in the first and second quarters of each calendar year. [171] They begin with a short risk survey, which is distributed in conjunction with other related information, such as each business unit's strategy and the output from prior-year assessments. Each business unit leader provides input on up to five risks key to their division's strategy in the next one to three years. Any perceived emerging risks are also discussed.

A Caterpillar executive said in an industry webinar that the corporation calls its risk management Business Risk Management (BRM) which is a title reflecting how the firm views the managing of risks as key to business success. Unlike many organizations, it does not only push risk identification down from the top but identifies risks with each business unit

and then pushes those risks up to the board of directors.[172]

The change in company revenue reflects the risk and volatility it faces. In 2008 it had $50 billion in sales that fell in 2009 to $32 billion and more than doubled to $70 billion in 2012. The ERM process is key to managing the volatility across its 125,000 employees and another 125,000 dealer employees operating in 50 countries.

Caterpillar bases its BRM unit in its corporate strategy unit instead of within the audit group that is common in most corporations. Reflecting the common approach that risk units tend to be small, Caterpillar has only seven employees in its corporate-wide risk effort. They serve as consultants to survey and coordinate with 30 business units to identify their risks. The risk unit collates and classifies the risks into one of several pre-determined categories. The risk group helps each business unit in a half-day assessment to review the survey comments and identify the groups' "true" risks. For those risks, each business unit team votes on the impact and significance. If there is a tie among two risks, the tie breaker is "velocity," or the rate at which the risk is growing. The business unit then defines its top risks, identifies its mitigation steps, and the timeline for them. It then reports that the risks have been mitigated and incorporated into its business strategies.

The risks from all 30 business units are shared with the vice presidents. The vice presidents synthesize the business unit risks into potential enterprise risks, which are then elevated to the audit committee, CEO and board of directors. Enterprise risks are categorized into one of four classes, compliance, operations, financial, and strategy. Out of a universe of 69 risks, eight to ten are typically classified as enterprise risks, the remaining are classified as business-unit risks. Each of the 69 are mitigated by a risk owner.

Home Depot also reports it has ingrained risk management into its strategic planning efforts. [173] In its annual SEC filings and reports to shareholders it lists numerous risks it must manage as the nation's largest home product retailer. [174] Strong competition from other retailers in the same market sector creates continuous risks. Changing consumer needs and trends are another common risk. Attracting qualified employees while controlling its labor costs also is a risk. Economic uncertainty plays a significant role in its risk because declining family income will reduce demand for home remodeling and repairs that can be discretionary purchases. Information technology systems are key to its ability to control inventory and manage costs. Risks to its information systems need to be managed to meet its objectives. Relationships and alliances with suppliers of proprietary products create risks if it is not able to obtain rights to distribute their products at competitive prices. Global supply chains represent additional risks to keeping merchandise stocked when needed, particularly seasonal items. It acts as a general contractor to install products and remodel homes for customers which is a business line that creates various liability risks.

Corporate Summary

Evolving corporate practice, U.S. regulations and investor expectations have combined to instill enterprise risk management in the corporate world. The evolution has been from risk management as a compliance or highly quantified financial practice to a broader, more strategic one. The quantification of financial risk remains as an integral part of the corporation's investment analysis efforts. However, those appear to be routine efforts that are standardized as the corporations analyze risks caused by foreign currency fluctuations, in-

flation risks, interest rate risks, and global market changes. Those risks are important but do not appear to rise to the board of director level because they have become standardized. What rises to the board of director level are risks which are much less predictable such as changes in customers' tastes, government regulation, political and economic upheaval, social trends, or major technology shifts that could render entire product lines obsolete. The shift from only financial and compliance risk management to strategic risk management makes enterprise risk management both more complex and also simpler. It is more complex because more variables are unpredictable, such as political upheaval around the world or technological breakthroughs. It is simpler because the identification of risk occurs by asking subject matter experts what they see emerging as risks. The examples from Caterpillar and Chevron show that risks are generated by business unit managers whose opinions are sought by the risk managers. The likelihood and impact questions illustrated in this guide are similar to those used by these corporations to analyze and prioritize their risks.

NCHRP Studies Summary

Two NCHRP studies examined the application of enterprise risk management in U.S. transportation agencies and both concluded that enterprise risk management remains in the formative stage. Several agencies have formal project risk management policies, and other have traditional risk management offices that focus upon health, safety and liability claims. However, only a minority of States have formal enterprise-wide risk management programs. This section summarizes the findings of the two NCHRP projects that assessed the state of the practice in U.S. transportation agencies.

NCHRP 20-24 Executive Strategies for Risk Management by State Departments of Transportation

This 2011 report was based upon a survey and interviews with U.S. transportation agency executives. [175] The research concluded that although many agencies are participating, enterprise risk management is truly in its formative stages in the United States. This study found that 13 DOTs reported having formalized enterprise risk management programs and found that a smaller number of DOT's have a comprehensive approach encompassing risk management at the enterprise, program, and project levels. The respondents from 35 of the 43 state DOTs (81%) reported that their DOT has formal, published risk management policies and procedures. However, none of these respondents felt that their agency was always successful at applying appropriate risk management strategies at the various levels of the enterprise. Twenty-six of the 43 states responding (62%) felt that they frequently apply the appropriate strategies, nine (21%) felt that they seldom applied the appropriate strategy, and seven (17%) felt that they never apply the appropriate strategies. Eleven of 43 agencies responding to the survey reported having formal project or program risk management.

NCHRP 08-36 Successful Implementation of Enterprise Risk Management in State Transportation Agencies

The primary objectives of this project were to identify, analyze, and describe the qualities of successful implementation of enterprise risk management programs in U.S. State De-

partments of Transportation (DOT). The study involved interviews of DOTs and ERM practitioners as well as a survey of 44 DOTs. The research concludes that state transportation agency ERM programs are still in their infancy. Although agencies are starting to receive tangible benefits from their ERM, they realize that mature ERM programs and agency-wide risk management cultures take time to develop.

In response to the project's survey, nine states reported having initiated or implemented formal, organization-wide ERM programs. The project team identified six states as having mature ERM programs that were subject to more in-depth analysis. One of those later was dropped because of a lack of statewide implementation. Five case studies were included in the report. The nine transportation agencies reporting ERM programs were from the States of Florida, Idaho, Massachusetts, Minnesota, Missouri, New York, Texas and Washington. Follow-up questions indicated that four of the agencies had formal enterprise risk management guidebooks or manuals, six had an executive committee in charge of risk management and five had used a risk register to map agency-level risks.

Three of the agencies investigated in the case studies had an ERM organizational unit in place to guide the ERM efforts. These formal ERM departments were each led by a senior-level individual who spearheaded the ERM processes at their agency. They also aided the ERM development and implementation process at their agency. Champions of the ERM efforts at the agencies with formal ERM departments were identified as the directors of the respective ERM divisions. WSDOT, which has the longest standing ERM program of those investigated, indicated that the ERM efforts are supported by many individuals throughout the agency's ERM division and led by the division's Director. Caltrans also has dedicated a formal ERM division that consists of individuals guided by the chief risk and ethics officer.

The other two agencies investigated do not have formal ERM departments but have individuals who led the ERM efforts and had also participated in the development and implementation of ERM at the agency. The ERM champion of MassDOT was the agency's Chief Financial Officer. The Director of Audit Operations championed the Missouri DOT's ERM efforts. Like the agencies with formal ERM divisions, these ERM champions coordinate the agency-level risk identification, assessment, and development of controls.

Case Studies of U.S. Practice

The following case studies summarize the risk management practices at three U.S. transportation agencies that have formal risk management programs.

CalTrans

The Office of Enterprise Risk Management was established by the agency's Executive Board in February 2013. At Caltrans, enterprise risk management is defined as a strategic business discipline that supports the organization's objectives by addressing the full spectrum of its risks and managing the combined impact of those risks as an interrelated risk portfolio. Caltrans practices risk management at the enterprise, program, district, and project levels. Its project risk management is highly developed and will be discussed in more detail below.

The Caltrans executive board formed the risk management office for several reasons. The

board wanted to support the agency's performance management efforts, it wanted to improve transparency, and it wanted to reduce the likelihood of malfeasance. Well-publicized cases of employee misconduct influenced the board's action.

The Caltrans enterprise risk management program also supports a statewide Financial Integrity and State Manager's Accountability (FISMA) Act that requires a robust set of internal controls within State agencies. Although the Caltrans enterprise risk management office is part of the department's larger audit unit, it focuses on more than financial compliance. It supports enterprise-wide risk management, which is seen as supporting the agency's performance management.

Caltrans bases its program on the ISO 31000 framework. Two staff members support the effort which operates on a biennial cycle of updating enterprise risks. The staff meet with each program and district office biennially for an approximately one-half day exercise. The risk assessment meetings allow participants to identify risks that create uncertainty for the agency's objectives. The objectives are specified in the meetings to keep the risk-identification efforts focused. Tactics such as posting the agency objectives on the wall and having participants use forms to fill out risks to the objectives are used to keep the risk identification focused upon the agency's top objectives. Workshops rely on brainstorming and expert interviews to identify the risks, which include both threats and opportunities.

Initially, more than 1000 risks were identified. The Office of Enterprise Risk Management evaluated all the risks based upon the frequency of their identification, the effectiveness or lack of effectiveness of controls, the likelihood and the impact of the risks. Using a modified "affinity" analysis technique, the staff summarized the 1000 risks down to a top 15 enterprise risks. Those were presented to the Caltrans Executive Board which periodically receives updates on the management of them.

The initial round of risk-identification workshops identified 672 threats and 327 opportunities, for just under 1000 risks. Those were identified from each of the 12 districts as well as from 10 major headquarters divisions. Three categories of risks were most commonly identified, those relating to program delivery, stewardship and workforce professional development. Each of those categories represented about 20 percent of the risks. Others were agency teamwork, integrity or ethical risks, innovation, commitment, safety, and transportation system performance. From those, 15 top enterprise risks were summarized. They are listed as risks but are not written as risk statements. Included are both threats and opportunities. The top 15 are:

- Develop our workforce
- Develop shelf-ready projects
- Enhance communication to improve reputation
- Engage and support employees
- Ethical employees and strong discipline
- Financial risks from external mandates
- Flexibility in environmental stewardship
- Foster partnerships
- Increase equipment and vehicle availability
- Innovative information technology
- Reinvent Caltrans culture

- Strategic cell phone deployment
- Streamline the project delivery process
- Strengthen contract and procurement processes
- Support skilled and ethical supervisors

Likelihood and impact values were applied both to the threats as well as to the opportunities. Among the highest rated opportunities was supporting skilled and ethical supervisors. Those were also rated among the highest threats, along with the need to strengthen the contracting and procurement process. Each risk was given an abbreviated alphanumeric identifier and plotted on a heat map based upon its ranking as an opportunity or a threat.

Caltrans emphasizes opportunities as well as threats. It created its own heat map that allows for opportunities to be rated on the left side of the map and threats on the right. Threats are still shown in the usual red and yellow colors, while opportunities are in shades of blue. Caltrans did not chose green for opportunities because some believed green indicated the risks did not need attention. The blue color is used to indicate that high-value opportunities need to be acted upon as do high-threat risks. In addition to being plotted on the heat map, the risks are also tracked in a risk register. The risk register is a simple format that uses color coding to indicate priorities, which are determined by the value generated from likelihood and impact assessments.

Risk owners are assigned to each risk. They are expected to take one of four types of risk actions, that being to mitigate, enhance, accept or avoid the risks. By mid-2015, the planned treatment was complete for 30 of the 52 identified risks, or performance measures were being established. An audit plan was developed to evaluate the controls associated with the risks identified in the discipline, financial report and professional development process. Among the risk responses implemented was the deployment of a statewide geographical positioning system (GPS) system for fleet management. Mandatory training was implemented for contract managers, and an ethics helpline was deployed. Caltrans also strengthened its centralized workforce planning efforts.

Caltrans wants to continue maturing its enterprise risk management program and hopes by 2020 to be at a “leadership” level in a risk maturity model. It is in the process of developing risk champions in each district and division. An ERM training development advisory team has been formed and the agency plans to deploy ERM training in 2016.

While the Caltrans ERM office supports risk management at the program and enterprise level, Caltrans also has an active project risk management process. It is based in formal agency policy that says risk management shall be applied to all capital and major maintenance projects for which the department has maintenance responsibility. [176] It says managers of minor projects of under $1 million are encouraged to maintain a project risk register. Managers for projects between $1 million and $5 million shall maintain a project risk register. For projects between $5 million and $100 million the project manager also will develop a qualitative risk analysis. For projects more than $100 million the project manager will also develop a risk register with a quantitative analysis.

The policy states that every project includes risks, but unfortunately they are not always communicated to the next phase of the project delivery process. Project risk management

reduces surprises through effective communication throughout the delivery process. The policy cascades risk management responsibility through 13 levels of the department from the chief engineer to the project delivery team members and task managers. The roles and responsibilities for each are summarized.

The Caltrans project risk management manual says the management of risk requires establishing a culture of risk management. [177] The risk management process should address the entire life cycle of a project from its inception to construction. The project manager, project sponsor, and project team jointly develop a risk register to identify, assess, quantify, and then monitor and control, project risks. The manual supports project risk management by providing:

- A consistent methodology for risk management;
- Techniques and tools;
- Data requirements for risk analysis input and output;
- Information on how risk management fits into the overall project management process, and;
- Guidance on how to respond to risks.

Caltrans believes its process is scalable to any size project. The level of analytical complexity increases with the project complexity or cost. It defines risk as "uncertainty that matters." It also differentiates "risk" from "issues." Issues are known, already-occurring problems that are being addressed. Risks are uncertainties that may arise.

Similar to the ISO framework, the Caltrans project risk management effort includes:

1. Risk management planning for how to execute risk management activities for a project.
2. Risk identification which identifies the possible risks.
3. Qualitative risk analysis that prioritizes risk for subsequent analysis.
4. Quantitative risk analysis that analyzes probabilistically the effect of the identified risks.
5. Risk response development activities to enhance opportunities and reduce threats.
6. Risk monitoring that tracks the risks, their mitigation and executes response plans.

The manual calls for a project risk management team to be formed comprising representatives from design, construction, project management, and other functional units involved with the project. The team should collectively have the expertise relevant to identify, assess and respond to the project's risks. Outside agency staff may be invited to participate if relevant. The guide stresses the value of a team approach. Discussion and listening provide more likelihood that risk impacts will be assessed properly.

The manual lists the roles of different members such as the project manager, district risk coordinator, project delivery team members, and the project risk manager. The manual recognizes that the complexity of the risk register will vary depending upon the complexity of the project, in keeping with the scalable intent of the Caltrans project risk management process. A written project risk management plan is not required for every project. The project manager and project development team decide if one is needed given the complexity of the project and its risks.

Caltrans provides tools and support to the risk management teams. A blank risk manage-

ment plan template is provided, as is a blank risk register. The manual provides the user with a checklist of steps for getting started such as determining the scale of the needed risk management effort, forming the team, using the risk register, and deciding if outside consultant help is needed.

One of the early steps for the project risk management team is risk identification, as it is in the ISO process. The manual explains the need to develop risk statements that help differentiate between the actual risk from its causes and its impacts. By focusing on the risk, mitigation efforts can be more effective. It provides examples for how to write a good risk statement that includes three parts: a cause, the uncertainty that arises from the cause, and the impact. Other tools include meeting-facilitation tips for how to elicit risks from the team, and lists from past projects that may spur further thinking. Site visits to help identify risks also are to be considered. Once identified, the risks are entered into the risk register.

Tables are provided with standard scaling for likelihood and impact to allow project risk teams to assess the risks they've identified. For instance, risks that could cause more than a 20 percent project cost increase are rated as having "very high" impact, compared to those that create a less than 5 percent cost increase which are "very low." Similar consistent scales are provided for likelihood. Based on the value of the likelihood and impact, the risks are placed in either the red, yellow or green section of the heat map.

In addition to the qualitative risk assessment which is conducted by staff based upon their judgment of likelihood and impact, Caltrans also uses software to develop quantitative risk assessments of complex projects. Consultant help is acquired to assist with the use of one of several commercial products. The likelihood and impacts are entered into the software and Monte Carlo simulation is used to generate a probabilistic analysis of the possible risk effects on costs or schedules. Curves can be generated as well as tabular data indicating the likelihood of different ranges of cost or schedule risks. The example from its manual is that a project may have a 90 percent chance of exceeding its current budget by $20 million and a 10 percent chance of exceeding it by $144 million. The results can be used in the project-development process to set cost and schedule targets, request a larger contingency, or determine the sensitivity of different risks. The output of the quantitative analysis can be used to rate the risks as high, medium or low and to then place the risks appropriately on the risk matrix, or heat map.

The next phase is for the project risk team to identify risk management strategies. These can be in one of four categories of avoid, transfer, mitigate, or accept. The manual emphasizes that some risks are opportunities that should be exploited. The risk management team then assigns the treatment strategies to the appropriate person or team and records it in the risk register.

Continuous monitoring by the risk manager and risk team occurs to ensure that new risks are identified and that the risk-response strategies are working. Regular risk meetings are to be held and the risk monitoring results communicated to the appropriate stakeholders.

Minnesota DOT

A new MnDOT commissioner of transportation implemented risk management when he took the helm of the agency in 2007. He came from FHWA and brought with him the agency's use of risk management to support its decision making and strategic planning.

The agency adopted a risk management framework that established the standards, processes and accountability structure to identify and manage risks across the agency. The framework was intended to allow leaders at all organizational levels to systematically evaluate implications of decisions related to the agency's highest goals and objectives, or "Key Results Areas." The MnDOT framework closely aligned the managing of risks with the achievement of its strategic priorities. Executive leadership (1) identified strategic risks to the agency's most critical goals, (2) determined strategies and goals for risk management, and (3) regularly reviewed results. The Minnesota DOT framework sought to manage risks at three levels, the strategic, business-line and project-level. The framework called for annual risk assessment of the strategic priorities by the senior leaders. At least monthly, the senior leaders were to review progress on key results and mitigation efforts. Senior leaders also were to review emerging risks that may require their management.

The framework called for business-line risks to be managed in five areas: the planning, preconstruction, construction, administrative, and operations management groups. Project managers were expected to manage risks commensurate with the complexity of their projects. Large, complex projects with significant risks were to be elevated to the Enterprise Risk Management Office for inclusion in the ERM Integrated Risk Register.

The Minnesota DOT framework identified an annual cycle of risk identification and update. Risks at the strategic, business and project-level were identified by conducting risk workshops across the divisions and districts. Risk registers were developed and a common terminology for assessing likelihood and impact was developed.

Definitions were provided in example risk matrices to categorize risks in ten different areas: reputation, business performance and capability, financial, security of assets, management effort, environment, legal and compliance, health and safety, quality, and stakeholder engagement. Definitions were provided for levels of impact including catastrophic, major, moderate, minor or insignificant. Likelihood impacts were defined to explain the categories of rare, unlikely, possible, likely, and almost certain. The framework also provides a number of definitions, including for risk, risk owner, risk register and other terms used in the agency's risk management process.

The framework explains risk management governance with the senior leadership setting the agency's strategic direction and managing strategic risks. It also develops the internal control systems, sets the risk appetite, implements ERM processes and takes other steps to cascade risk management across the organization. Business-line management groups own risks to products and service delivery. They were identified as being responsible for evaluating and establishing service line targets and levels of service based on risk tolerance, and agency commitments. Business-line management groups were identified as responsible for the risks in their service areas, while district management groups were responsible for business-line risks in their districts. The Chief Risk Officer directed the Enterprise Risk Management Office that coordinated risk management across the organization, assisted districts and divisions, and facilitated consistent risk assessments. An Enterprise Risk Management Implementation Team comprised of representatives from districts and offices supports the chief risk officers in developing and implementing the ERM framework.

MnDOT integrated risk management into its strategic decision making. The asset management section of Chapter 9 of this report summarizes how risk was identified and managed in the agency's draft asset management plan. Risk also figured prominently in the 20-year

financial strategy document known as the Minnesota 20-Year State Highway Investment Plan (MnSHP). The agency used risk to strengthen the planning process to better understand the tradeoffs between funding levels. [178] References to risk permeate the MnSHIP plan referencing the agency's consideration of how to reduce risks to Minnesotans on the transportation network, how to avoid risks to assets caused by deterioration, and how to manage risks to the agency's bond rating if it can't maintain adequate investment levels. The report references the Statewide Performance Program and the District Risk Management Program to summarize its statewide priorities and how districts manage risks to those priorities with each district.

Since its inception in 2007, the department's enterprise risk management program has evolved as senior management changed. A former chief risk officer offered advice to officials in other States to keep the ERM program focused upon specific, achievable objectives. Setting goals that are overly broad and then attempting to manage risks to them is less effective than setting realistic objectives and then managing the practical risks to them.[179]

Washington State DOT

The Washington State Department of Transportation (WSDOT) practices risk management at many levels and represents one of the most mature risk management processes among U.S. transportation agencies.

The DOT efforts reflect a statewide focus on enterprise risk management in Washington. The Washington State Department of Enterprise Services provides traditional and enterprise risk management support to state agencies. Traditional risk management services include assisting with insurance and loss-reduction efforts. It also provides resources for understanding and implementing enterprise risk management at the different agencies. The Enterprise Services agency produced a Risk Management Basics handbook for agencies in 2010. [180] It provides definitions, explanations for how to apply enterprise risk management and explains different risk-treatment strategies.

At the DOT, an Office of Enterprise Risk Management coordinates risk management efforts. These spread across many program areas including safety, business operations, asset management, and projects. A refined project-risk-management focus provides a framework for extensive management of risks to projects.

The risk management efforts support performance, optimized decision making, supports strategic goals and objectives, and helps to balance tradeoffs. The enterprise risk office helps program managers identify their risks and it provides in-house tools to help manage them. Among the tools are a risk management guide. As with the other states' guides, it provides definitions of likelihood and consequence scales. It also leads users to consider risks in the areas of agency credibility, transportation system performance, environment, financial, department performance, legal and compliance, critical support services, and health and safety. It also provides the heat-map-like risk matrices for users to plot risks visually based upon their likelihood and consequence.

The agency provides sample risk registers for personnel. The completed registers are kept electronically in a shared location so they can be viewed both by the risk managers and others in the department. The online registers show the likelihood and severity of the risks

both numerically and plotted on the risk matrix. A "slider bar" tool is available where users can change the probability, consequence and agency exposure level to generate a color-coded risk rating. Others tools map known highway system risks such as unstable slopes. These can be used for both risk management and asset management.

The risk management analysis is used along with the agency's performance reporting system to communicate to legislators and other stakeholders. The risks and opportunities to achieving major program objectives are reported, such as the risks to its Target Zero and other major strategic objectives. When a new initiative, such as hard-shoulder running, is considered its competing risks are evaluated. Allowing drivers to use shoulders during peak hours could relieve congestion but also creates the threat of vehicles striking nearby guard-rail and barrier, or that the shoulder can't withstand the loadings.

The WSDOT also uses insurance to mitigate its risks. It is self-insured for tort action, requires contractors to have protective liability insurance, and the agency insures some of its bridges and ferry boats. Some other assets are insured for property damage or business interruption claims including for earthquakes, floods and terrorism.

WSDOT applies risk-based analysis to many of its common investment problems. It examined the risk-return of highway lighting on traffic safety. Lighting can be expensive and as budgets became tighter it examined whether the costs of lighting reduced the risk of crashes. An analysis indicated that having lights on from dusk to dawn was not worth the cost. The lighting did little to reduce crashes in dusk and dawn light. Late at night traffic volumes were so low that lighting did not seem to reduce crash risks. The agency found it could reduce lighting, save money, and not increase crashes. It also used a risk-based framework to prioritize ferry vessel preservation. It ranked its vessels based upon risk factors such as likelihood of vessel failure and used the rankings for vessel-investment decision making.

Because of its geography, geology, and climate, the WSDOT incorporated risk management into efforts to seismically retrofit bridges and prepare for extreme climatic event. (See Chapter 9) The seismic retrofit program prioritized bridges by their vulnerability and importance for emergency evacuation and response. The climate change risk vulnerability assessment also supports risk-management efforts to plan for events and to make the transportation system more resilient.

The climate change risk assessment informed WSDOT that floods in western Washington State will likely increase in magnitude because of the combined effects of warming and increased winter storm intensities. In eastern Washington, projected spring floods are expected to be reduced because of a loss of snow cover. These forecasts can factor into decisions on projects and maintenance activities. The increased risk projected by the climate analysis can be a tie breaker if investments in two otherwise equivalent projects are under consideration. The risk to different types of facilities are considered with Interstate Highway System and "lifeline" routes being rated with the highest risk priority while low-traffic routes are rated with the lowest risk-response priority. The risk-based climate change assessment led WSDOT to conclude that:

- Climate change intensifies known risks, such as flooding risks to culverts and roadways;
- It reinforces the value of maintenance efforts and seismic retro-fit programs, and;

- The assessment provided a means to capture the knowledge of field staff and incorporate it into decision making.

WSDOT also has a robust project-risk-management process. It faces a very active Legislature that specifies as budget line items projects with planned budget amounts and scheduled construction years. The WSDOT Project Risk Management Guide helps to manage the risks to both the cost estimates and schedules. It notes that estimates have two components, a base cost estimate and the risk component. A base cost is estimated then the risk register records the uncertainties that could be threats or opportunities. As with the Caltrans project risk management process, WSDOT's process is scalable to the size and complexity of the project.
As with the other guides, it provides definitions and steps for risk management. For projects over $10 million, risk-based estimating workshops are required. For projects less than $10 million, qualitative analyses are conducted based upon an online guide. For projects over $25 million, a cost assessment workshop is conducted, while for projects over $100 million there is an even more sophisticated Cost Estimate Validation Process Workshop. The most complex Cost Estimate Validation Process Workshop could last three to five days.

The WSDOT project-risk-management process emphasizes that one number does not represent a sound cost estimate, particularly early in the project-development process. Rather a range of costs are more reasonable and does not mask the uncertainty inherent in a single cost estimate. The cost range represents the possible additional costs or savings that could be experienced based upon the uncertainties contained in the risk register. The risk assessment replaces general and vaguely defined contingency with defined risk events. Risk events are defined by their probability and their impact.

The project risk management guide provides definitions, steps, risk registers and advice for how and when to conduct risk workshops. Risk registers and regular review meetings allow a project management team to keep abreast of risks and to reduce uncertainty as the project advances. As the project get closer to the engineer's estimate phase, the number of uncertainties are reduced and the project budget, scope and schedule clarifies.

The risk identification process and the risk matrix recognize opportunities as well as threats. They allow for the assessment of the likelihood and impact analysis of both threats and opportunities. The analysis leads to a project risk management plan that includes the defined risks, their triggers, their probability, likelihood, their owners, and the status of management response.

For expensive and complex projects, the department will rely on quantitative risk analysis that uses Monte Carlo simulation to develop ranges and curves for cost and schedule. The quantitative analysis develops a range for different uncertainties which produces best cases, worst cases and various intermediate estimates for cost and schedule. The probability for each type of range is estimated from the Monte Carlo simulation. A most likely estimate is provided but so are estimates of the probability of its best-case and worst-case scenarios.

Australian Risk Management Summary

Australian national, state, and local governments are expected to practice enterprise risk management as a basic government function such as strategic planning and managing fi-

nancial controls. The national government enacted the Public Governance, Performance and Accountability Act of 2013 that specifies minimum "good government" practices for all federal agencies and subdivisions. It specifies risk management as a part of a coherent system of governance and accountability to more effectively ensure that government entities meet high standards of governance, performance, and control.

One analysis summarized seven controls government officials must provide to comply with the act. [181] Three of the seven relate to risk. They include establishing policies for controlling risks, assessing risks with providing government resources to other entities, and ensuring that risk taking does not undermine proper management of public resources.

The Australian government's minister of finance issued a risk policy based on the act. [182] The policy puts risk management within a larger framework of essential government practices. These illustrate the close linkage of risk management to performance and public reporting. The policy says key elements of the national Public Governance act include establishing systems of control, managing risks, adopting corporate plans, and producing annual performance statements. The policy says its goal is to embed risk management into the culture of national entities so that understanding of risk leads to well informed decision making. It establishes nine elements that agencies must comply with including:

- Establishing risk management policies
- Establishing a risk management framework
- Defining responsibilities for risk
- Embedding risk management in business processes
- Developing a positive risk culture
- Communicating and consulting about risk
- Understanding and managing shared risks
- Maintaining risk management capability, and
- Reviewing and continuously improving the management of risk.

The policy says an organization's risk management policy should link the agency's risk management framework to its strategic objectives. It recommends communicating the accountabilities, responsibilities, and expectations across the agency.

Among other objectives, agencies should develop a "positive risk culture" with a set of shared attitudes, values, and behaviors of how the agency considers risks in daily activities. It defines a positive risk culture as one that considers both threats and opportunities. A positive risk culture also identifies, assesses, communicates, and manages risks at all organizational levels.

The degree to which risk management is seen as an essential government function is evident in the findings of a review commission whose efforts preceded the Public Governance, Performance and Accountability Act. [183] The Commonwealth Financial Accountability Review that was conducted between 2010 and 2012 concluded that four basic reforms were needed:

- Improved financial reporting to Parliament
- More mature approach to risk across the national government
- Improved government productivity, and
- Reduced red tape.

References to risk permeate the annual reports of Australian transportation agencies. The State of Victoria's Department of Economic Development, Jobs, Transport and Resources was formed in 2015 and incorporates the state's former transportation agency. Its annual report notes it has an Audit and Risk Committee that operates with a mandate similar to those in the U.S. publicly traded corporations. [184] The risk committee has one internal member and three external ones. It provides oversight of key audit and risk functions such as:

- Financial and performance reporting
- Internal and external auditing
- The risk management framework
- Effectiveness of management information systems
- Accounting practices
- Legal compliance.

The agency bases many compliance functions upon risk. It performs vehicle safety inspections of recreational vehicles based upon a risk-based audit plan. Inspections of mining operations also were based upon a risk-based assessment as were audits of maritime training organizations.

The State of Queensland's Department of Transport and Main Roads also includes a strong emphasis on risk management in its governance processes. [185] It relies on a series of cascading leadership teams with varying levels of responsibility. The most senior is the executive leadership team which oversees organizational performance with five governance committees, one of which is audit and risk. The others include information and systems, safety and wellbeing, infrastructure and investment, and finance.

The audit and risk committee assists with:

- Integrity of the financial statements and internal controls
- Legislative and regulatory compliance
- Internal risk management and controls
- Internal audits.

Among its annual accomplishments were progress in building and improving risk management capability, monitoring, and reporting within the department. Although the Audit and Risk Committee has primary responsibility for risk management, the other four governance committees also referenced risk-based areas under their areas of responsibility. The safety and wellbeing committee reviewed the department's safety risk profile while the financial committee report references consideration of many financial risks.

In reporting on its annual performance, Transport and Main Roads references its management of its risks concurrent with its accomplishment of its objectives. It says it applies a robust risk management framework to manage strategic risks that may impact on the department delivering its business objectives. Its annual report for 2014-15 says in part:

> *We recognize that risk management is a key element of good corporate governance and is a fundamental part of managing our business. Our philosophy supports a structured approach to managing risks. Our objective is to develop capabilities in risk management to ensure consistent and effective assessment of risk across the department. We acknowledge that successful risk management will be achieved*

through the development of a culture where risk management is embedded into business processes.

Transport and Main Roads reports that its Audit and Risk Committee reviews compliance with legislative and regulatory risk management requirements, and monitors its effectiveness. Business areas are required to conduct risk management activities and reports according to the department's risk framework. A quarterly risk report is compiled for the executive leadership team and the Audit and Risk Committee. The executive leadership team meets regularly to review the risks and management strategies.
Key strategic risks are identified as part of the annual strategic planning cycle. All business areas identify risks that may impact their business objectives, and they select strategies to manage them. The department reported focusing upon managing the risks to the following key strategic objectives:

- Developing transport solutions to drive prosperity
- Planning and investment priorities
- Disruptive events, such as storms or other incidents
- Sustainable infrastructure and services

The State of New South Wales' transportation agency also reports having a robust enterprise risk management process. Annually, Transport for New South Wales attests in its annual report that its risk management process complies with the State's Internal Audit and Risk Management Policy for the NSW Public Sector. [186] That policy requires all State agencies to have an independent audit and risk committee which is to be an integral component of the agency's corporate governance. The risk committee's responsibilities are to address:

- Internal controls
- Risk management
- Corruption and fraud prevention
- External accountability including financial statements
- Applicable laws and regulations
- Internal and external audit.

The audit committee is to be chaired by an independent person with appropriate subject matter expertise.

Among the audit committee's duties are to review the effectiveness of the mandatory enterprise risk management process required by the State policy. The ERM practice is to be consistent with the Australian/New Zealand risk management standard which is nearly identical to ISO's. The policy says each agency's enterprise risk management program must ensure that risk is defined broadly to include all relevant business risk categories. Also risk management is to be integrated with the department's strategy setting, decision making, governance, plans, and procedures.

The State policy goes on to require agencies to define and communicate their approach to risk and provide guidance on how to integrate it into everyday work activities. Required components are to identify risk objectives, linkages to business plans, key accountabilities, and periodic review of continual improvement efforts. The State policy spells out comprehensive requirements for the agency leadership to approve a risk management policy, determine risk appetites, and ensure the risk management policy is implemented and regular-

ly reviewed.

Transport New South Wales' officials attest in their annual report that risk management is a core capability and key contributor to the agency's success. The annual report says the agency embeds its risk framework into its business processes to comply with the State policy and with the Australian/New Zealand risk standard. It says risk management is ingrained into business units who include material risks in their business plans. They report to the executive staff quarterly the status of their risk management efforts. The executive committees review the risks quarterly and look for emerging risks and opportunities. The executive committees also provide leadership to continually improve the risk management performance.

Among the many risks cited in the annual risk reports were a $200 million increase in the maintenance budget to manage risks to asset conditions, which are described as "service levels." High-risk intersections were identified for red-light speed cameras. Pedestrian "count down" timers were tried to reduce the risk of pedestrian injuries. A motorcycle crash risk-management effort called Ride to Live was launched. A ranking of crash-worthiness of 227 makes and models of used cars was produced. Risk analyses were used to deploy public transit police officers. Also, the responsibilities for different aspects of the agency's risk management process were cited throughout the annual report.

Chapter 11 Advanced Risk Tools

Summary

Effective tools and techniques directed towards managing risks provide important information and present options that support decision-making. As agencies begin to implement enterprise risk management, they may consider the use of such tools to advance risk management practice at multiple levels.

This chapter discusses tools that can allow the incorporation of uncertainty and variability in the decisions that influence agency objectives. At the time of preparation of this report, many transportation agencies nationwide are addressing MAP-21 and the subsequent Fixing America's Surface Transportation Act (FAST) requirements for TAMPs which require, (i) identifying long term strategies to achieve and maintain the asset condition and performance in a state of good repair, and (ii) the forecasting of funds needed to achieve these projected asset conditions for at least a ten-year period. This requires estimating the investment levels needed to maintain assets in a desired condition and making revenue forecasts, including addressing the risks to such forecasts. Additionally, agencies may have to decide from amongst multiple mutually exclusive and complex options.

Examples discussed in this chapter show how three different state agencies use risk registers to summarize their identification, analysis, and prioritization of risks to assets. These examples show the use of the tool and illustrate how agencies can adapt the risk register to their specific needs. In addition, this chapter discusses tools that support a quantified analysis of program, project, and activity risks. Several of them can be used for detailed analysis by quantifying the impacts and related probabilities surrounding different options. Since financial aspects play an import role in decision-making and the implications of various risks can be measured in financial terms, the chapter puts particular emphasis on tools used to assess the impacts and management of risks related to funding needs and revenues. It discusses both deterministic and random computations incorporating variability of revenues and expenditure forecasting using simple Excel tools. It discusses tools that use Monte Carlo simulations that incorporate probability in the analysis to evaluate financial risks. The chapter also discusses the Decision Tree tool that can help simplify a selection from amongst many mutually exclusive and complex choices with different outcomes.

Risk Registers

One of the simple tools used to prioritize risks is the risk matrix. The ISO standard on risk techniques discusses [187] various approaches to identifying and assessing risks. These include the use of both quantitative and qualitative ratings to rate the likelihood and severity of risks. Risks are shown in a matrix that lists the likelihood rating of each risk on the vertical axis and the consequences rating on the horizontal axis. Similar matrices have been used by agencies to evaluate the impact of agency risks.

The steps include the identification and evaluation of various risks followed by mapping

them in a risk matrix that shows the likelihood rating and consequences rating. This mapping allows decision-makers to get a summary view of the impact and severity of the risks, compare risks and prioritize them. The agency's risk tolerance and resource availability also influence the number and types of prioritized risks that an agency will be able to realistically address. Once the risks are prioritized, they are listed in a risk register. Following are examples of the risk matrices and risk registers developed by three state departments of transportation (DOTs).

Vermont Risk Register

The Vermont Agency of Transportation (VTrans) example shows a simple tool that the agency uses to evaluate risks. Figure 28 shows the risk matrix detailing the likelihood, consequence and impact ratings used by VTrans to prioritize risks. The five color-coded risk rating categories are Nonessential, Low, Medium, High, and Critical. Figure 27 shows how these risk-rating categories link to a matrix containing various categories of "Consequences" and "Likelihood" as established by the agency.

The VTrans risk matrix shows that the risks that are expected to have a critical impact on the agency are (1) those that will have a catastrophic consequence and will either be highly likely or almost certain to happen, or 2) those that will be almost certain to happen and will

Consequence		Likelihood				
		Rare	Unlikely	Likely	Highly Likely	Almost Certain
		1	2	3	4	5
Catastrophic	5	5	10	15	20	25
Major	4	4	8	12	16	20
Moderate	3	3	6	9	12	15
Minor	2	2	4	6	8	10
Insignificant	1	1	2	3	4	5
Risk Rating Category		Nonessential	Low	Medium	High	Critical

have a major consequence. These are shown in the upper right corner of the risk matrix.

Figure 27 Vermont DOT Risk Matrix; Source: Vermont Agency of Transportation

The information about the risk ratings for all the risks analyzed is entered into a Microsoft Excel workbook which constitutes VTrans' risk register. This register addresses risks in six functional areas of 1) bridges, 2) pavements, 3) traffic and safety, 4) budget, planning and programming 5) data management systems, and 6) ancillary assets. The risk register includes approximately 300 highest risks.

Risks associated with each of these six major categories are detailed in separate tabs of the risk register. Major risks from each of the six areas are then compiled into a tab titled "Enterprise Risks". This tab of the risk register shows the critical risks from each of the six areas that can impact the agency. Figures 28, 29, 30, and 31 show snapshots of enterprise risks associated with the asset categories of pavements, bridges, budget, planning and programming, and data management and systems. Mitigation strategies are also shown for bridges, pavements, and data management and systems.

Pavements													
	Risk Event	Primary Impact	Likelihood	Consequence	Expected Value	Likelihood	Consequence	Expected Value	Mitigation Strategies				
Materials	If the quality of materials continue to decline	then this will result in lower quality products	Very Likely	Catastrophic	Critical	4	5	20	specification changes	change material type	VTrans to take over designs	change treatment type	warrantees
Asset Management	If we don't select the right treatment	then modeling data will be more variable	Almost Certain	Major	Critical	5	4	20	monitor and review				

Figure 28 Critical enterprise risks from pavements. Source: VTrans

Bridges											
	Risk Event	Primary Impact	Likelihood	Consequence	Expected Value	Likelihood	Consequence	Expected Value	Mitigation Strategies		
Finance	If there is not sufficient planned bridge maintenance funding	then bridges will deteriorate prematurely	Almost Certain	Major	Critical	5	4	20	dedicated bridge maintenance funds		
Data	If there is a lack of available bridge maintenance data	then improper maintenance will be performed on the wrong bridge at the wrong time	Almost Certain	Major	Critical	5	4	20	store and track bridge maintenance data		
Leadership	If roles and responsibilities remain unclear and continue to change	then important activities will not get done and poor/ill informed decisions made	Almost Certain	Major	Critical	5	4	20	improve strategic planning	improve communication between leadership and staff in light of reorganization	
Finance	If funding is reduced to the bridge program	then the number of deficient bridges may increase	Almost Certain	Major	Critical	5	4	20	justify the existing program based on performance measures	communicate implication of reduced funding	
Enforcement	If bridge load posting are not legally enforced or self enforced	then this may result in bridges carrying overloads causing increased bridge wear, damage, or failure	Almost Certain	Major	Critical	5	4	20	outreach with local users so they understand load postings and dangers	communicate risk to legislature - remove agriculture exemption	integrate 511 with bridge postings, work the law enforcement
Leadership	If there is no IT support for design software	then designs may be out of AASHTO design specifications or have errors/omissions and inconsistencies	Almost Certain	Major	Critical	5	4	20	purchase support and maintenance with software	IT needs to be more service oriented toward "client"	

Figure 29 Critical enterprise risks from bridges. Source: VTrans

Budget, Planning, and Programming								
	Risk Event	Primary Impact	Likelihood	Consequence	Expected Value	Likelihood	Consequence	Expected Value
Asset Management	If we don't link asset management needs with resources to deliver asset treatments (with people)	then right treatment at the right time may not be done	Almost Certain	Major	Critical	5	4	20
Schedule	If large projects have schedule changes	then we may not be able to obligate all of our federal funds	Almost Certain	Major	Critical	5	4	20

Figure 30 Critical enterprise risks from budget, planning and programming. Source: VTrans

Data Management and Systems													
	Risk Event	Primary Impact	Likelihood	Consequence	Expected Value	Likelihood	Consequence	Expected Value	Mitigation Strategies				
Finance	If we are not able to associate project costs to specific assets	then we cannot properly track treatment costs	Almost certain	Major	Critical	5	4	20	build asset identification into the project plans	improve field data collection processes	define clear expectations	train to collect data consistently	having updated inventories
Data	If data is not transparent across the agency	then this could result in duplication of efforts	Almost certain	Major	Critical	5	4	20	improved data tools	improve communication	training staff on available data portals	define easy access	identify a consistent way of accessing data
Data	If there is no quality control of data	then it will lead to incorrect performance reports and estimates/budgets (actions and decisions)	Almost certain	Major	Critical	5	4	20	better data validation	stewardship of data	additional resources to work on quality control	clear business rules around data	
Data	If there is resistance to a cultural shift toward enterprise information management	then it will slow down TAM efforts	Almost certain	Major	Critical	5	4	20	create champions	management support of change	incorporate into performance reviews	communications	
Workforce	If statewide initiatives like ERP require tech staff involvement	then tech staff will be unavailable for AM projects	Almost certain	Major	Critical	5	4	20	prioritize resources	increase resources	choose not to participate		
Leadership	If there are lack of clear business requirements	then it will result in poor data (and systems) affecting correct designs affecting preservation, maintenance and daily operations	Almost certain	Major	Critical	5	4	20	business process management	have units document business process rules	communication across units to ensure continuity of business processes	standardization	

Figure 31 Critical enterprise risks from data management and systems. Source: VTrans

Risks at lower levels can percolate up and impact an agency's ability to achieve its strategic goals and objectives. This link can be seen in VTrans risk register. VTrans uses the information in its risk registers to link each risk to its strategic goals and objectives, so that the impacts of these risks can be evaluated. The agency has identified one or more strategic objectives within the five agency goals. Table 21 shows how each risk in the six asset cate-

gories is linked to the five agency goals and objectives.

Table 21 is shows that 51 risks affect 74 agency objectives in the category of "Ancillary Assets, Transit, Rail and Aviation", 36 risks affect 45 Bridge objectives, 79 risks affect 118 Budget, Planning and Programming objectives, 27 risks affect 34 Data Management Systems objectives, 21 risks affect 35 Pavement objectives and 84 risks affect 111 Traffic and Safety objectives. In total, 298 risks affect 417 agency objectives. The table shows that the risks in the categories of (i) budget, planning, programming, and (ii) traffic and safety, impact the most number of the agency's strategic goals and objectives.

Table 21 The number of risks associated with VTrans' strategic goals and objective. Source: VTrans

Objective	Ancillary Assets, Transit, Rail, Aviation	Bridges	Budget, Planning, Programming	Data Management and Systems	Pavement	Traffic and Safety	Total
Goal 1: Provide a safe and resilient transportation system that supports the Vermont economy							
1.1	4	5	2		1	33	45
1.2	3						3
1.3	2						2
1.4	1						1
1.5	2						2
1.6	5	1	3	1			10
1.7	1	3	2				6
1.8			5				5
Goal 2: Preserve, maintain, and operate the trans. system in a cost and environmentally resp. manner							
2.1	10	10	15	2	13	12	62
2.2	10	3	43	19	4	21	100
2.5			9				9
2.7	1		1				2
2.8	8		1				9
2.9	6	10	20	4	10	8	58
2.10	3					2	5
2.13	1					2	3
2.14	2		1				3
Goal 3: Provide Vermonters energy efficient travel options							
3.1		3				19	22

3.2	9		1				10
3.3			1				1
3.4							
3.5	1						1
Goal 4: Cultivate and continually pursue innovation, excellence, and quality customer care							
4.1	1		5			9	15
4.2		1			1	1	3
4.3		5		1		3	9
Goal 5: Develop a workforce to meet the strategic needs of the Agency							
5.1				2		1	3
5.2	2	3	9	5	3		22
5.3	2	1			3		6
Miscellaneous and Total Breakdown							
Total	74	45	118	34	35	111	417
# of Risks	51	36	79	27	21	84	298

NCDOT Risk Register

At the time of writing of this report, the North Carolina Department of Transportation (NCDOT) is in the process of developing its risk-based asset management plan to meet MAP-21 requirements. Agency personnel state that one of the benefits of the risk identification and analysis exercise for NCDOT has been that the effort made the agency "more mindful" of the impact of risk in conducting its business.

NCDOT staff used brainstorming and subject matter expertise to identify the probabilities of risks. They also considered if the impact of the event was local, regional, statewide or beyond the state. These were very pertinent to risks addressing hurricanes, flooding events and budget issues. Risks relating to the pavement management systems and information technology were discussed by a smaller group of subject matter experts. NCDOT formed two committees to identify and prioritize risks to pavements and bridges. Several factors including funding uncertainty, natural disasters such as flooding and hurricanes, and population growth were considered in the effort. Figure 32 shows the risk matrix used by NCDOT to rate risks.

The risks were shown in the agency's risk matrix as follows:

1. Highest Risks (Color coded Red): Risks that have a high probability of occurrence and can have a severe impact on the agency
2. Intermediate Risks (Color coded Yellow): Risks that have increasing impact and increasing probability of occurrence.
3. Low Risks (Color coded Green): Risks that have low probability of occurrence and low impact on the agency.

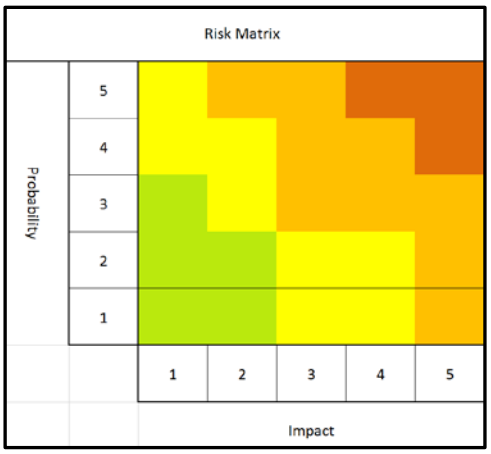


Figure 32 NCDOT Risk Matrix; Source NCDOT

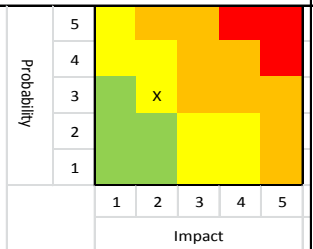
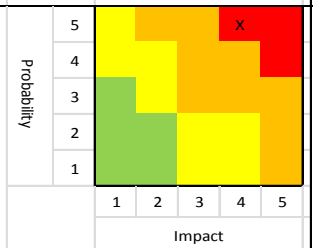
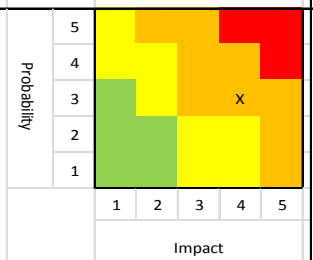
Category	Failure Cause	Effect	Threat or Opportunity	Probability	Impact	Risk Matrix	Response	Risk Contingency Response Plan	Actions	Responsibility	Resources
	Sample Data	Sample Data	Sample Data	3	2		Sample Data	Sample Data	Sample Data	Sample Data	Sample Data
Funding	funding shortfall	Fewer projects, less optimal treatments, decreased pavement condition ratings, reduction in personnel, RPO's funding decreased, MPO's funding decreased	Threat	5	4		evaluate impacts	Alternate funding sources, track impacts on system and report to Legislature, educate decision makers about MAP21 requirements, move roads to local jurisdiction, adjust our targets.	Monitor budget and evaluate contingencies for -10% and -20% budgets. Analyze impact on roadway condition.	Program Development Unit, Pavement Management Unit. Guidance from Chief Engineers office.	Asset Management Plan, Pavement Management System
Hurricanes or flooding	Major event hits NC	washouts, drainage or pipe failures, weakened pavement structure, heavy loads immediately after event, diversion of personnel and equipment, lack of connectivity for citizens and freight, potential diversion of funds (up to 20% out of pocket), economic impacts to businesses in affected area.	Threat	3	4		Preplan and evaluate	Hurricane planning, move personnel to affected area, preposition equipment and materials, TIMS to inform citizens, preplanned detours, hurricane evacuation routes	Table top hurricane planning exercise. Conference calls before, during and after event. Review issues to improve plan.	State Maintenance Operations Unit, Division offices and local maintenance yards.	Asset Management Plan, SAP records

Figure 33 Snapshot from NCDOT's Risk Register for Pavements; Source: NCDOT

The risk matrix was used by the agency to develop its risk register. Figures 33 and 34 provide a snapshot of the NCDOT risk register that addresses the asset category of pavements. The risk register includes the type of risk, effect, probability, impact, risk matrix, response, contingency response plan actions and responsibility. It also shows the resources that NCDOT has assigned to address the risk responses.

Figure 33 shows that the "failure cause" of "funding shortfall" within the "Funding" risk category has a 5 out of 5 rating for probability and a 4 out of 5 rating on impact. The risk register identifies that the effects of the risk of funding shortage include (i) fewer projects, (ii) less optimal treatments, (iii) decreased pavement condition ratings, (iv) reduction in personnel, and (v) decrease in funding to Rural and Metropolitan Planning Organizations. The risk contingency plan indicates seeking alternate sources of funding, tracking and communicating to the legislature the impact of the reduction in treatments on system conditions, and educating decision makers about the impact of MAP-21. Another response identified to address the risk of funding shortage is to move roads to local jurisdiction and adjust the condition targets to reflect the reduction in funding. The action to address this risk is to evaluate the impact of a 10 percent and 20 percent reduction in budget on the pavement condition as a contingency

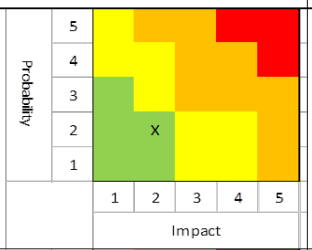
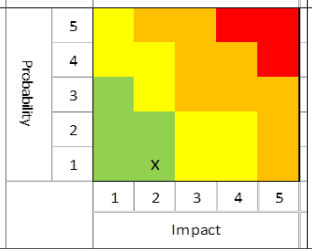
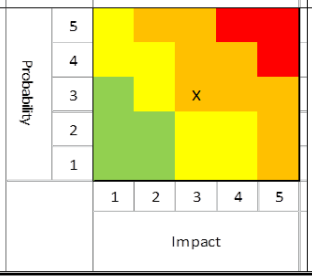
Category	Failure Cause	Effect	Threat or Opportunity	Probability	Impact	Risk Matrix	Response	Risk Contingency Response Plan	Actions	Responsibility	Resources
Pavement Material Shortage	Cement or Asphalt shortage	Delayed Construction, higher cost means less work, pavement condition declines during delay, only lower quality materials available, could change pavement type	Threat	2	2		Monitor and act if shortage occurs.	Stockpile materials, track material trends, find alternate sources, change materials, adjust project delivery date.	Evaluate impacts of delayed material deliveries to project completion.	Construction Unit, Resident Engineer, Pavement Management Unit, Materials and Tests.	Material Supplier reports to contractors. Construction publications.
Pavement Material Defects	Alkali Silica Reactivity	Pavement failure at Depth, Increased maintenance costs, increased ride roughness	Threat	1	2		Prevent construction of new ASR.	Test aggregates, enforce specifications, educate inspectors and resident engineers.	Evaluate aggregate sources and train resident engineers having concrete projects.	Materials and Tests, Construction Unit, Resident Engineers.	Current specifications, best practices.
Climate Change	Climate change raises average temperatures and level of ground water table.	Asphalt used in pavement is not adequate for higher temperatures so rutting develops, higher GWT results in decreased support under pavements, increased frequency of extreme events (see hurricanes and flooding). Some roadways may be flooded in coastal plain.	Threat	3	3		Monitor and change as needed.	Track changes in temperature and GWT levels to make design changes.	Evaluate asphalt mixes at "new" temperature ranges to see if action is taken.	Materials and Tests, Geotechnical Engineering.	Laboratory test results, National oceanographic atmospheric administration predictions.

Figure 34 Snapshot from NCDOT's Risk Register for Pavements; Source: NCDOT

Other risks identified for the pavement asset category as shown in Figure 34 include pavement material shortage, pavement material defects, climate change, and hurricanes or flooding.

These examples show the use of a risk matrix and risk register to capture the impact and actions being planned to address some categories of risks based on historic data, research or recommendations from subject matter experts.

There are many factors that can influence an agency's ability to achieve the goals detailed in its TAMP. Risks to each of these factors have to be understood, closely monitored and mitigated appropriately. As the NCDOT examples show, the agency has identified funding shortages as one of the important risks to achieving agency objectives, to implementing its TAMP, and to achieving the requirements of asset management.

Washington DOT Risk Register

Washington DOT (WSDOT) has been using risk management at the project level since the late 1990s. In 2007, the Secretary's Executive Order E1038.00 directed the agency to implement Enterprise Risk Management (ERM). The intent was to identify and plan for risks that could occur within two years that could harm or enhance the agency's ability to deliver

its commitments and strategic plan.

Since the early stages of this effort, all the risks were captured in one risk register that was developed using Excel. Since the implementation of the ERM effort in 2007, more than 700 risks were tracked in the register. The number of risks being tracked grew so large, the agency recognized that having all the risks input in one Excel risk register posed challenges. To address this issue, the agency is in the process of developing a SharePoint site where users can enter risks similar to the single Excel risk register. In this case, the data is saved in an Access database.

The following discussion covers the Excel tool that was used by the WSDOT and the refinement that is currently under way. The four major steps in the WSDOT process are:

1. Risk Identification;
2. Qualitative Evaluation of the Risk;
3. Risk Analysis, and;
4. Risk Response Plan.

The DOT has a process that details each step and agency personnel are trained on the methodology and tools to use in their ERM effort. Risks are marked as impacting the following eight categories:

1. Department Performance
2. Financial
3. Health and Safety
4. Transportation Systems Performance
5. Environment
6. Core Workforce and Competency
7. Legal and Compliance
8. Reputation and Credibility

Based on the analysis of the types of risks that were identified by agency personnel, the WSDOT also groups risks into the following twelve group events:

1. Resources- Staffing
2. Process
3. Resources-Equipment
4. Systems
5. Resources-Funding
6. Man-made Events
7. Training
8. Data
9. Political
10. Policy
11. Organizational, and
12. Natural Events

Figure 35 shows the WSDOT scoring matrix for likelihood and severity based on a scale of 1 to 5, with 5 being the highest or worst.

Severity Score	Levels of Risk				
5	Low	Med.	High	Very High	Very High
4	Low	Med.	High	High	High
3	Low	Low	Med.	High	High
2	Low	Low	Med.	Med.	Med.
1	Low	Low	Low	Med.	Med.
	1	2	3	4	5 Likelihood Score

Figure 35 WSDOT Risk Likelihood and Severity Rating; Source: WSDOT

Risks are categorized into four levels: (1) Low, (2) Medium, (3) High and (4) Very High. For every risk identified, a risk statement is created and scored based on likelihood and severity, and assigned one of the four levels of risk. A risk can impact more than one of the eight categories of risks. A worksheet in the Excel risk register is used by subject matter experts to score each risk based on likelihood and impact. Table 22 shows an example of the Risk Identification and Risk Evaluation Worksheet that was being used by WSDOT.

Table 22 Risk identification and risk evaluation component of WSDOT risk register; Source: WSDOT

Risk Identification		
Risk Number	1	
Risk Statement		
Risk Category	-	
Risk Description		
Risk Trigger		
Qualitative Evaluation of the Estimated Impact		
Evaluator List	Likelihood (1-5)	Severity (1-5)
Evaluator 1		
Evaluator 2		
Evaluator 3		
Evaluator 4		

The information from the scoring is summarized in another worksheet in the risk register. Table 23 shows an example of such a summary pertaining to Information Technology risks from the WSDOT risk register. As shown in the example, a risk can impact multiple catego-

ries and the impact can differ in each of the categories.

Table 23 Risk statements with level of risk by category; Source: WSDOT

				Level of Risk for Impacted Categories							
						Very High	High	Med.	Low		
ID	Risk Statement	Event Group	Comp. Index	Health & Safety	Finan	Dept. Perf	Legal Compl	Reput. & Cred	Trans Sys Perf	Core Wrkf & Comp	Env
4_IT	IT Disaster Recovery Plan Inadequate for Risk Event.	Process	26.9			2					
23_IT	New requests for applications/software do not move forward due to lack of adequate project management staff.	Resources (Staffing)	25.3								
1_IT	Loss of the Collision Location & Analysis System (CLAS) and other systems.	Systems	14.9								
8_IT	The WSDOT servers, network or Internet not available.	Systems	11.2								
26_IT	WSDOT staff do not have adequate equipment or software to perform basic tasks.	Resources (Equipment)	9.8								

The scores from these detailed Worksheets from the risk register are summarized into a Summary Worksheet. Figure 36 shows an example of the Summary Worksheet scoring for Information Technology risks in WSDOT.

Number of Risk Impacts in Relationship to the Area of the Risk Impact (Effect)						
		(# of Impacts)				
Rank	Risk Impact Categories	Very High	High	Med	Low	Group Subtotal
1	Financial		2	2	5	9
2	Trans. System Performance		2	0		2
3	Reputation & Credibility		1	1	4	6
4	Dept. Performance			6	10	16
5	Core Workforce & Competency			1		1
6	Legal Compliance				6	6
7	Health & Safety					
8	Environment					
	Total	**0**	**5**	**10**	**25**	**40**
		0.0%	**12.5%**	**25.0%**	**62.5%**	**100.0%**

Figure 36 Example of Scores for Information Technology Risks in WSDOT. Source: WSDOT

This summary view provides decision-makers the information on the resources to allocate for mitigating different risks.

The scoring heat map also indicates the level of governance for each risk. The risk governance for the four different levels are as follows:

1. Very High: These are color coded red. These risks threaten the continuation of the Department and possibly major impact to its reputation. These require prompt action and intervention from the Secretary of Transportation, or Governor.

2. High: These are color coded orange. Controls exist to address these risks, however, additional action is required to manage these risks. These risks can impact the agency's ability to achieve strategic objectives and are managed by the executive management team.
3. Medium: These are color coded yellow. These are risks which threaten completion of a critical WSDOT function. Controls exist but additional action may be required. These are managed at the Division level.
4. Low: These are color coded green. These risks could affect routine procedures and practices and affect routine operations. They are managed at Director/Office level.

WSDOT organizes the mitigation strategies into the following five categories:

1. Passive Acceptance – Doing nothing and accepting the consequences if the event occurs
2. Active Acceptance – Developing a contingency plan to execute should the risk event occur
3. Transfer – Shifting risk from one party to another. Transfer can be an insurable risk that is shifted to another party (the insurer) by means of an insurance policy.
4. Reduction – Implementing actions to reduce the probability that a risk will occur and/or reduce the impact should the uncertainty occur, or to increase the probability and/or take advantage of a benefit if the uncertainty were to occur.
5. Avoidance – Eliminating a specific threat, usually by removing the cause.

Over the years, the number of risks being tracked in the Excel files has increased and managing the risks using Excel worksheets became cumbersome. A migration of the risk registers to SharePoint is expected to make it easier for users to input new risk statements and update existing ones. The agency will continue to summarize the data and present reports as shown in Figure 36 and Table 23.

The summary of risks in the risk register is made available to decision makers. A risk team also meets monthly with the transportation secretary and the leadership team to discuss the high-level risks and the status of mitigation. The agency has a requirement to present the top risks to the state legislature during the biennial budget cycle. The summary of risks is also used by the agency to meet this requirement.

Funding Risks

Uncertainties associated with availability of funding and persistent funding shortfalls have plagued transportation agencies nationwide for decades. These have taken center stage since the financial crisis of 2008. Funding constraints which continue to be a bottleneck in

the successful implementation of any asset management plan are a continuing reality for most transportation agencies nationwide. As of January, 2016, global oil prices are seeing a significant decline. States that have economies linked to oil, including Oklahoma and North Dakota, are facing funding challenges on account of declining revenues. These states are therefore unable to project the revenue they can expect to earn from year to year with any reasonable degree of confidence. Aside from economic uncertainties, some states are projecting that the transportation choices being made by both the younger generation and the aging population are resulting in lower revenues from state fuel taxes. For example, the Maryland DOT's Long-range Plan reports that the trends indicate a move to transit with projections for no increase in vehicle miles traveled (VMT) and a slight decrease in per capita VMT in Maryland. The plan states that the changing travel trends also show a 14% increase in transit ridership with the weekly transit ridership growing from 320,000 riders per month in 2006 to 366,000 riders per month in FY 2012. Compounded over a 10-year plan period, the financial risks resulting from such uncertainties become significant and will need to be appropriately addressed in any asset management planning effort.

The TAMPs being developed by agencies to address the MAP-21 requirements will vary in the categories of assets covered by them, but at a minimum, they will include bridges and pavements. In developing the TAMP, agencies will be forecasting the asset conditions they plan to achieve during the TAMP period along with reliable forecasts of the costs associated with delivering these asset conditions. Small changes in rates of inflation, or in construction, material and other costs, can accumulate over the TAMP period and have a rippling effect on an agency's ability to deliver the planned program of projects. Also, there is no guaranty that future trends will mimic historical performance of the uncertain cost variables. As they prepare their asset management plans, agencies will need to account for risks associated with the costs of achieving the long-term asset condition targets established in the TAMP.

In order to achieve their long-term goals, agencies will need to systematically deliver projects and activities each year that result in the forecasted condition targets being met for each asset category. Successful delivery of these projects and activities in the TAMP will necessitate the deployment of sufficient resources and reliable allocation of funds to meet their projected costs. Agencies will therefore need to also forecast their anticipated revenue sources, availability, and magnitude, with a reasonable degree of confidence. Variability and uncertainty in the availability of funding is a big risk in the planning and delivery of the agency's TAMP. Unmitigated funding deficits can derail the delivery of the TAMP, and just as in the case of costs, past funding performance is no guaranty of revenue trends that can be anticipated in the future. Funding shortages and related financial uncertainty are among the critical risks that agencies will have to consider as they plan their long-term strategies.

MAP-21 requires preparation of a financial plan associated with the TAMP that incorporates risk analysis and details the financial strategy the agency intends to implement to mitigate such risks and successfully deliver the projects as planned. It will require clarity on the funds needed (the "Uses") and the funding resources that are projected to be available annually ("Sources") to meet these needs. It also will require a discussion of projected funding gaps and if they can be bridged. Given the uncertainty over the availability of funds from traditional sources, decision-makers will need to consider the critical risks and proactively plan for timely mitigation in order to successfully deliver the TAMP.

To illustrate, consider the projected (simplified) sources and uses of funds that form part of the financial plan associated with a 10-year TAMP for a sample DOT. These are shown in Tables 24 and 25.

Table 24 Projected Sources of funds for a sample DOT during its 10-year TAMP period.

PROJECTED SOURCES OF FUNDS FOR A SAMPLE DOT												All figures in $ (millions)
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
State Funds												
State Fuel Tax	120	144	144	144	144	144	144	144	144	144	144	1,560
State Sales Tax	60	66	66	66	66	66	66	66	66	66	66	720
License and Registration Fees	55	61	61	61	61	61	61	61	61	61	61	660
Toll Revenues	30	33	33	33	33	33	33	33	33	33	33	360
General Funds	60	60	60	60	60	60	60	60	60	60	60	660
State Bonds	-	-	-	189	171	239	272	129	-	-	-	1,000
Subtotal State Funds	325	364	364	553	535	603	636	493	364	364	364	4,960
Federal Funds												
Federal Programs	285	294	302	311	321	330	340	351	361	372	372	3,639
Other Federal Programs	-	-	-	-	-	-	-	-	-	-	-	-
Federal Bonds	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal Federal Funds	285	294	302	311	321	330	340	351	361	372	372	3,639
Local Funds												
Local Match	10	11	5	5	5	5	5	5	5	5	5	66
Subtotal Local Funds	10	11	5	5	5	5	5	5	5	5	5	66
Total	620	668	671	869	860	938	981	848	730	740	740	8,665

Table 25 Projected Uses of Funds for a sample DOT during its 10-year TAMP period.

PROJECTED USES OF FUNDS FOR A SAMPLE DOT											All figures in $ (millions)
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
Pavement Program												
Overall (NHS + Non-NHS) Pavement Condition Rating (%)	77%	78%	77%	79%	81%	83%	85%	83%	81%	78%	76%	
Rehab & Replace	60	60	60	95	95	95	95	72	60	65	65	822
Preservation	36	52	52	56	64	68	72	76	68	68	68	680
Maintenance	9	13	13	14	16	17	18	19	17	17	17	170
Subtotal Pavement Program	**105**	**125**	**125**	**165**	**175**	**180**	**185**	**167**	**145**	**150**	**150**	**1,672**
Bridge Program												
Structural Deficiency - NHS and Non-NHS (%)	18%	21%	22%	19%	17%	15%	14%	14%	16%	18%	21%	
Rehab & Replace	60	70	78	150	150	170	160	95	71	75	75	1,154
Maintenance	45	90	95	95	100	110	105	100	85	82	83	990
Subtotal Bridge Program	**105**	**160**	**173**	**245**	**250**	**280**	**265**	**195**	**156**	**157**	**158**	**2,144**
Maintenance												
Traffic	10	15	15	15	15	20	20	20	20	20	20	190
Drainage	5	5	10	10	10	12	12	15	15	20	20	134
Winter	25	25	30	30	35	35	35	35	35	40	40	365
Other	55	40	40	50	50	55	55	55	60	60	65	585
Subtotal Maintenance	**95**	**85**	**95**	**105**	**110**	**122**	**122**	**125**	**130**	**140**	**145**	**1,274**
ITS	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**55**
Safety	**10**	**35**	**30**	**25**	**25**	**25**	**25**	**25**	**30**	**30**	**30**	**290**
Other Assets	**25**	**25**	**20**	**20**	**15**	**20**	**20**	**20**	**25**	**25**	**25**	**240**
New Construction	**65**	**70**	**60**	**95**	**100**	**120**	**135**	**70**	**-**	**-**	**-**	**715**
Local Projects	**40**	**30**	**30**	**55**	**50**	**50**	**45**	**40**	**40**	**40**	**40**	**460**
Debt Servicing												
Existing obligations	125	85	85	80	30	-	-	-	-	-	-	**405**
New State Bonds	-	-	-	24	50	84	122	141	139	133	127	**819**
Subtotal Debt Servicing	**125**	**85**	**85**	**104**	**80**	**84**	**122**	**141**	**139**	**133**	**127**	**1,224**
Programming/Project Delivery	**20**	**20**	**20**	**20**	**20**	**20**	**25**	**25**	**25**	**25**	**25**	**245**
Administrative Expenses	**25**	**28**	**28**	**30**	**30**	**32**	**32**	**35**	**35**	**35**	**35**	**345**
Total Uses	**620**	**668**	**671**	**869**	**860**	**938**	**981**	**848**	**730**	**740**	**740**	**8,664**

It can be noted from Tables 24 and 25, that the financial plan shows the availability of sufficient Sources to meet projected Uses for each year of the plan period. However, the important factors to consider would be whether annual variability of each of the projected numbers has been taken into account. For example, Table 24 shows an assumption by the DOT that the State Fuel Tax revenues will go up by 20% in 2016 (from 2015) and then stay constant during the rest of the plan period. Questions that need to be answered include: What is the basis of such an assumption? Has the DOT considered annual fluctuations in State Fuel Tax revenues? What were the historically observed annual fluctuations? Is it reasonable to expect that such historical trends will be repeated in the future, or are there other factors, such as macro-economic factors that might influence future trends? What are the chances of State Fuel Tax revenues being different than that projected by the DOT and what strategies will the DOT implement in such an event?

Similarly, Table 25 shows the projected pavement Rehabilitation and Replacement costs to be constant at $60 million per year for the first three years and then constant for the next three years at $95 million per year. Questions that arise include: Do these projected costs account for inflation and if so, at what rate? Do these projected values account for uncertainty in material, labor and construction costs? If the actual costs are higher and the reve-

nues lower in a given year than those projected, what strategies will the DOT need to implement to deliver its programs and meet its strategic goals? Will the agency need to cut some programs, reduce performance targets or make other trade-offs to balance the Sources of funds with the Uses?

These are the types of questions that agency leaders will grapple with as they finalize their TAMPs and associated financial plans. While there are no crystal balls available to predict future outcomes with confidence, risk analysis tools can assist an agency in estimating the impact of the uncertainties, accounting for them in the financial planning process, taking steps to minimize or mitigate such impacts, and in communicating to their stakeholders the variabilities they are dealing with.

Several tools can be utilized to analyze and manage the financial risks associated with preparing an asset management plan. These vary in complexity from simple spreadsheet tools for performing deterministic analyses using historical data, to increasingly complex analyses that incorporate the impacts of variability of various parameters using stochastic methods. Several tools, progressively increasing in complexity and functionality, are introduced in the following sections along with illustrative examples to facilitate an understanding of methods available to address financial risks in the asset management planning process.

Financial Risk Tools

There are several spreadsheet-based tools of varying complexity and sophistication that can assist decision makers as they analyze financial risks in the asset management planning process. A balance between the complexity of the tools being used and the magnitude of risks being managed is important. Black box tools where the logic used to compute and present the risk management options are hidden from the decision-makers can be intimidating and lower the confidence in the options being presented. Often simple tools, by virtue of their simplicity and transparency, can serve the purpose of providing the information needed for decision-making. An approach that can enhance the implementation of risk management is to start with simple tools and systematically include those that are more complex, depending on the need and the increasing level of confidence they may provide. The tools discussed in this report are not exhaustive but provide a flavor of the options available to users.

Table 26 Historical Sources and Uses for a Sample DOT (for illustrative purposes only – not based on actual data)

HISTORICAL SOURCES AND USES FOR SAMPLE DOT ($ Millions)																			
Category	YEARS																Mean	Range	
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015		Min	Max
Sources																			
State Funds	440.8	452	454.8	445.2	439.2	444	436.8	438	429	441	450.6	468	477	481.2	486	480			
Annual Change		2.5%	0.6%	-2.1%	-1.3%	1.1%	-1.6%	0.3%	-2.1%	2.8%	2.2%	3.9%	1.9%	0.9%	1.0%	-1.2%	0.6%	-2.1%	3.9%
Federal Funds	112.0	112.3	128.2	162.9	196.7	207.7	246.4	262.8	297.5	315.8	332.6	334.8	350.4	371.5	384.8	409.0			
Annual Change		0.3%	14.2%	27.1%	20.7%	5.6%	18.6%	6.7%	13.2%	6.2%	5.3%	0.6%	4.7%	6.0%	3.6%	6.3%	9.3%	0.3%	27.1%
Local Funds	4.5	4.7	5.0	4.9	6.1	5.8	5.8	6.2	5.5	9.7	9.8	10.3	10.1	10.3	10.7	11.0			
Annual Change		4.4%	6.4%	-2.0%	24.5%	-4.9%	0.0%	6.9%	-11.3%	76.4%	1.0%	4.6%	-1.5%	2.0%	3.9%	2.8%	7.5%	-11.3%	76.4%
Total Sources	**557.3**	**569**	**588**	**613**	**642**	**657.5**	**689**	**707**	**732**	**766.5**	**793**	**813**	**837.5**	**863**	**881.5**	**900**			
Annual Change		2.1%	3.3%	4.3%	4.7%	2.4%	4.8%	2.6%	3.5%	4.7%	3.5%	2.5%	3.0%	3.0%	2.1%	2.1%	3.3%	2.1%	4.8%
Uses																			
Pavement Costs	123	126	130	136	142	146	152	156	162	170	176	180	186	192	196	200			
Annual Change		2.4%	3.2%	4.6%	4.4%	2.8%	4.1%	2.6%	3.8%	4.9%	3.5%	2.3%	3.3%	3.2%	2.1%	2.0%	3.3%	2.0%	4.9%
Bridge Costs	245.3	250	259	270	284	291	305	314	325	340.5	353	361	371.5	383	391.5	400			
Annual Change		1.9%	3.6%	4.2%	5.2%	2.5%	4.8%	3.0%	3.5%	4.8%	3.7%	2.3%	2.9%	3.1%	2.2%	2.2%	3.3%	1.9%	5.2%
O&M and Admin Costs	189	193	199	207	216	220.5	232	237	245	256	264	272	280	288	294	300			
Annual Change		2.1%	3.1%	4.0%	4.3%	2.1%	5.2%	2.2%	3.4%	4.5%	3.1%	3.0%	2.9%	2.9%	2.1%	2.0%	3.1%	2.0%	5.2%
Total Costs	**557.3**	**569**	**588**	**613**	**642**	**657.5**	**689**	**707**	**732**	**766.5**	**793**	**813**	**837.5**	**863**	**881.5**	**900**			
Annual Change		2.1%	3.3%	4.3%	4.7%	2.4%	4.8%	2.6%	3.5%	4.7%	3.5%	2.5%	3.0%	3.0%	2.1%	2.1%	3.3%	2.1%	4.8%

Basic Spreadsheet Tools

Basic spreadsheets such as Microsoft Excel can be effectively used to analyze the impact of financial uncertainty, be it with respect to estimating future costs or projecting future revenues. For illustrative purposes, consider the historical Sources and Uses for a sample DOT shown in Table 26 for a sixteen-year period between 2000 and 2015. Note that the figures shown in this table do not represent actual data from a DOT and are shown purely for illustrative purposes.

Evaluating the various Sources of funds, it is seen that the annual change in the state funds varies approximately between -2% and +4%. However, the federal funds and local funds show a much wider degree of variability, without a discernible pattern. The mean value of the historical annual rate of change of state funds is computed to be 0.6%. If the agency were to assume that future trends in state funds will be similar to those seen in the 2000-2015 period, then projected revenues over a 10-year TAMP period can be computed within a spreadsheet and the results depicted in graphical form. Figure 37 illustrates the projected values of state funds using the historical mean rate of change as well as at the high and low limits of the rate of change that were observed in the sixteen-year period. Figure 37 shows that in Year 2025, the projected value of state funds could vary between a possible low of approximately $390 million to a high of approximately $710 million, i.e., a range of approximately $320 million. If the mean value of the annual change were used, the projected value of the revenues from state funds in 2025 would be approximately $510 million. The likely value will probably fall somewhere within the wider range, however, the relevant point to note here is that the uncertainty or risk of availability of state funds can be illustrated through such simple tools.

A similar exercise can be completed for projected Uses. It is observed that the annual change in the Uses, whether they be for pavements, bridges or maintenance and administrative costs, ranges between approximately 2% and 5%, with a historical mean value of approximately 3.3%. Although other factors may contribute to this annual change, assuming that the overall scope of work has not changed materially from year-to-year, the bulk of the annual change may be attributable to inflation. Once again, assuming that the historical pattern of inflation will continue, projected Uses for the TAMP period can be estimated using the minimum, mean and maximum values of the annual rate of change observed. Figure 38 depicts the projected bridge costs for the TAMP period on this basis. It can be seen that the projected annual bridge costs in 2025 can vary from a low of approximately $490 million to a high of approximately $650 million with constant annual inflation rates of 2% and 5%, respectively. The use of the historically observed mean value of the annual inflation rate of 3.3% projects the 2025 Bridge costs to be approximately $550 million. The likely values may vary within the bounds illustrated from year to year. Once again, the charts prepared using basic spreadsheet tools illustrate the uncertainty and variability in costs. Additional charts that superimpose Sources and Uses may also be used to illustrate whether the forecasts envision any gaps or surpluses to occur over the plan period.

Similar analyses can also be performed for a variety of different situations, for example, to evaluate the impact of changes in input costs of specific materials such as steel, cement, oil, etc., on project construction costs.

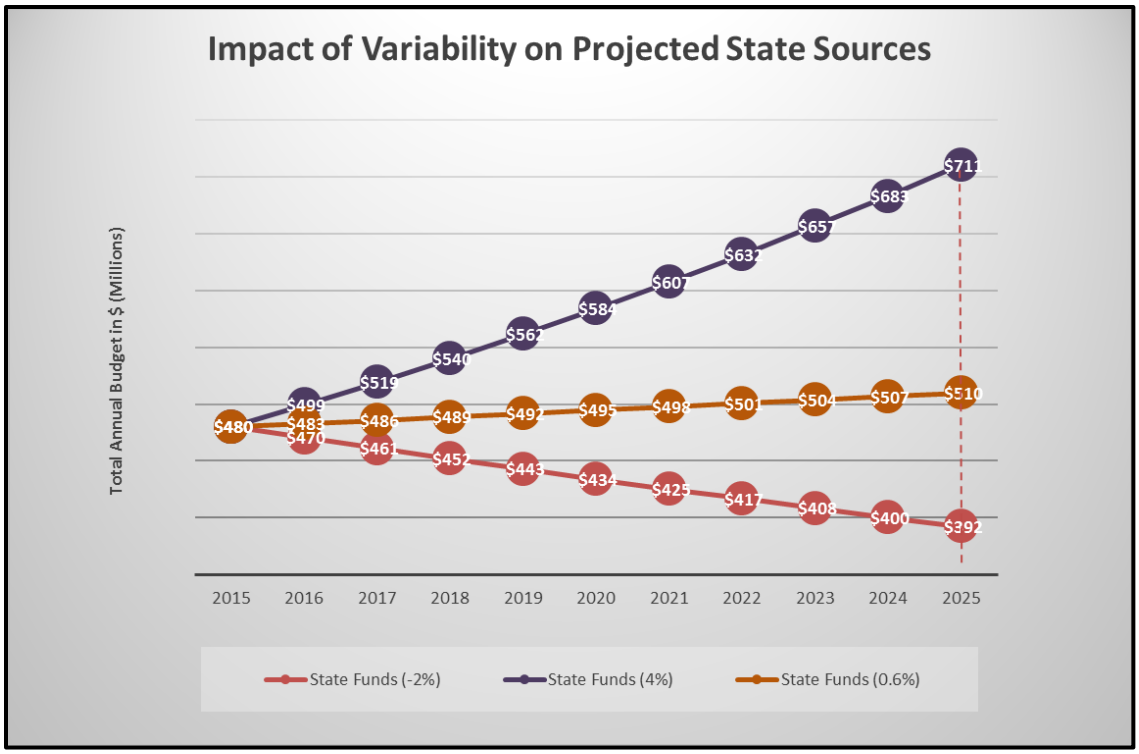


Figure 37 Variability of projected State Funds during plan period.

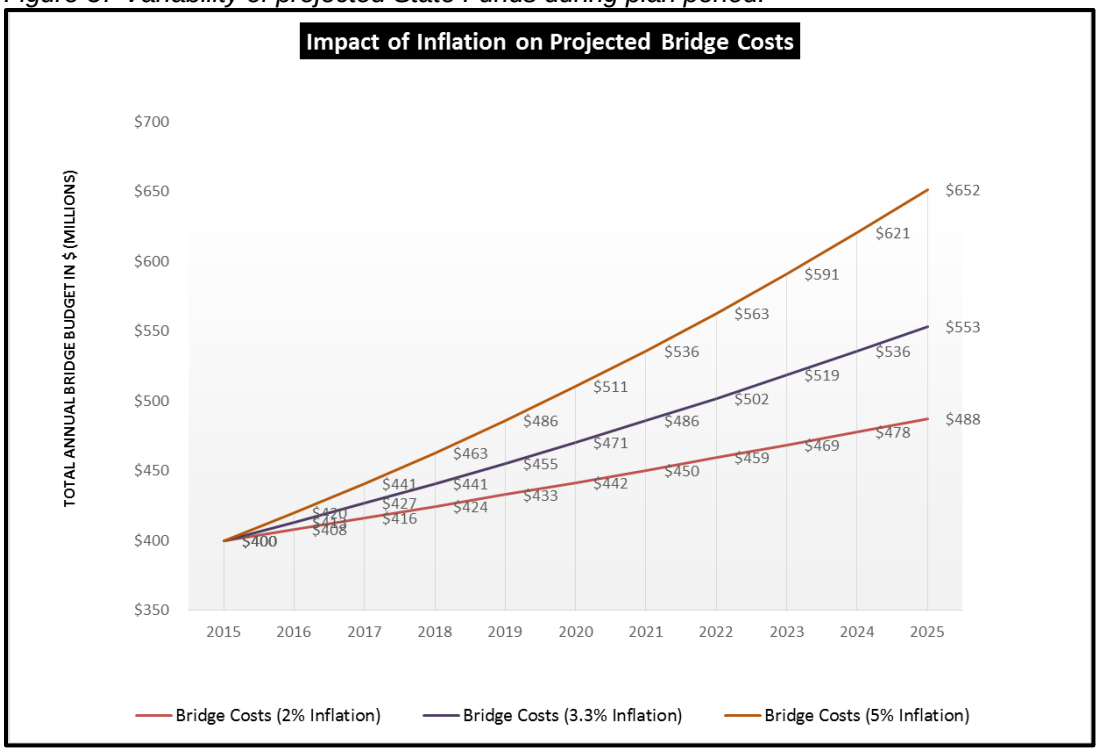


Figure 38 Variability in Projected Bridge Costs due to Inflation during plan period.

Incorporating Elements of the Delphi Technique

The utilization of spreadsheet tools can be refined by incorporating elements of the Delphi technique into the process. This technique incorporates a systematic and interactive forecasting method that relies on a panel of experts. The process of using recommendations from a panel of experts to provide important input to facilitate decision making has often been utilized by transportation agencies. The simple Microsoft Excel examples discussed previously made assumptions of future trends based on historical performance – both in the annual rate of change of revenues and the annual rate of change in costs. Based on the assumptions used, the illustrations showed the estimated likely values of certain Sources and Uses and also the outer limits of the projections. However, in recognizing that future outcomes may be influenced by new realities and may not be reflected in past performances, it may become necessary to obtain the guidance of experts, such as economists, financial experts, technical experts, construction experts, etc., as applicable, to help understand and estimate the uncertain parameters and thereby manage their uncertainty. Using guidance from the panel of experts to estimate the uncertain parameters, the necessary risk analyses can be performed and various options can be identified to manage the risks. Decision-makers can review the options presented, and based on the circumstances and their agency's level of risk tolerance, make decisions on how to treat the risks.

The previously described simplified example of the sample DOT (Table 26) is used in this section to illustrate the use of the Delphi technique. In this example, projections of the Total Uses (consisting of annual costs for pavements, bridges, operations, maintenance and administration) and the Total Sources of funds are evaluated for risks due to inflation and annual variation in revenues, respectively. Table 27 summarizes the recommendations made by the Panel of Experts on the annual inflation rates and the annual rate of variation in Total Sources to consider during the plan period. Note that these may be different from what was observed historically, and are representative of what the expert panel considers relevant for the TAMP period. In recognition of the uncertainties associated with these parameters, the panel has provided a range of values to consider for inflation rates and for the annual variability in Total Revenues. In addition, the panel's recommendations include an equal probability of occurrence within the specified ranges for the uncertain parameters.

*Table 27 Summary of recommendations from expert panel for variability in uncertai*n parameters during TAMP period.

Parameter	Recommendations from Panel of Experts			
	Base Case		Annual Variability Range*	
Annual Inflation		4.0%	3.0%	5.0%
2015 Total Uses (Annual Costs for Pavement, Bridge, O&M, Admin - $ Millions)	$ 900			
2015 Total Revenues from all Sources ($ Millions) and Annual Variation (%)	$ 900	1%	-3%	5%
* Inflation and Revenues to vary within the specified ranges during the TAMP period with equal probability of occurrence				

Deterministic Computations Incorporating Variability

Computations similar to those described in Basic Spreadsheet Tools can be used to evaluate the risks of variability in the Total Sources and Uses based on the values of uncertain input parameters suggested by the panel of experts as summarized in Table 27. Computations shown in Figures 39 and 40 illustrate the ranges within which the Total Uses and Total Sources can vary over the TAMP period. Figure 39 shows that, depending on the inflation rate assumed, the Total Uses can increase to approximately between $1.2 billion and $1.5 billion by 2025, i.e., a likely variation of about $300 million. With an equal probability of occurrence, the total costs incurred by the agency can therefore be expected to fall any-

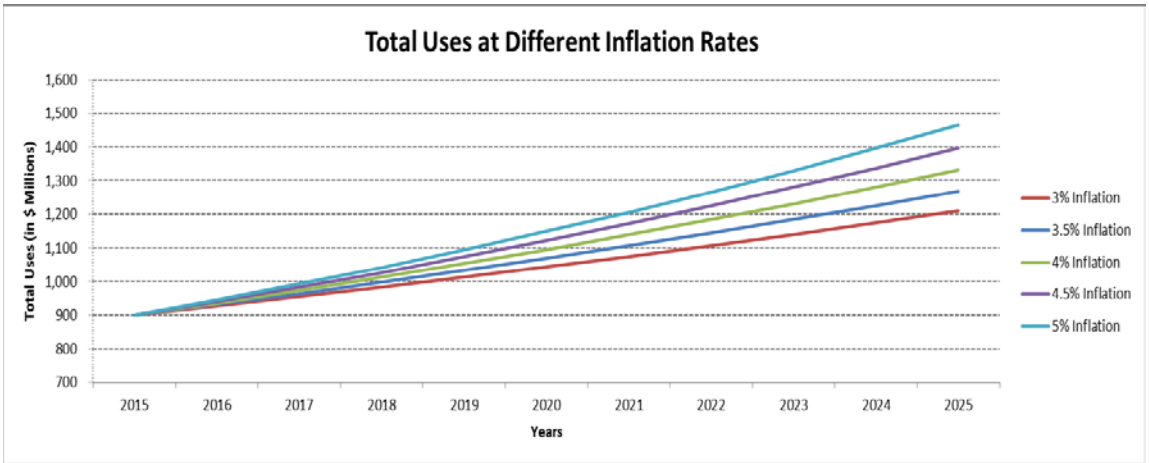


Figure 39 Projected uses at different inflation rates.

where within the range illustrated by the lines for 3% inflation and 5% inflation.

Figure 40 shows that if the sources declined at 3% every year, then by 2025, the amount of revenues the agency could expect would be approximately $660 million, rising up to approximately $1.5 billion in the most optimistic scenario of a sustained annual increase of 5%.

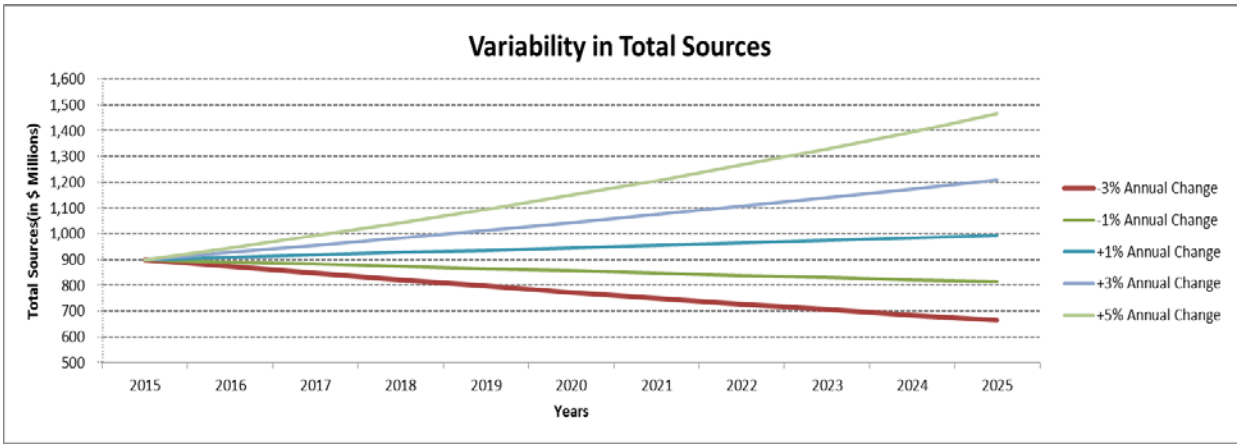


Figure 40 Variability in Projected Sources at different rates.

Clearly the potential variability in revenues of approximately $800 million by 2025 is a material risk for the DOT that will need to be addressed by decision makers.

If the base case assumptions recommended by the expert panel are used for the projections, the Total Uses would rise to approximately $1.3 billion in 2025, whereas the Total Sources would rise to only about $1 billion, resulting in a projected gap of approximately $300 million. This is more specifically illustrated in Table 28. Table 28 shows that using the base case recommendations from the expert panel, the DOT would project a funding gap in each year of its 10-year plan period, growing from a deficit of $27 million in 2016 to a deficit of $338 million in 2025. For convenience, the table also shows the present values of these projected cash flows (Sources, Uses and Gaps) computed for the TAMP period. The computed present values show an aggregate funding gap of $1.311 billion over the TAMP period.

Table 28 Projected Sources, Uses and gaps (including Present Value computations) during TAMP period using Base Case recommendations from expert panel for variability in uncertain parameters

Computation of Projected Sources, Uses and Gaps for the Next 10 Years using Base Case Recommendations from the Panel of Experts												
Inflation Rate		Present Day	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Annual Variation in Sources		Present Day	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Cost/Revenue	Present Value	Years										
Category	(Years 2016-2025) †	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total Uses*	$9,000	$900	$936	$973	$1,012	$1,053	$1,095	$1,139	$1,184	$1,232	$1,281	$1,332
Total Sources*	$7,689	$900	$909	$918	$927	$937	$946	$955	$965	$975	$984	$994
Projected Gaps*	($1,311)	$0	($27)	($55)	($85)	($116)	($149)	($183)	($219)	($257)	($297)	($338)

* Annual variability using Base Case Recommendations from panel of Experts; All figures in $ (Millions)

† A 4% Discount Rate was used to compute Present Value

The present values can also be used to evaluate the sensitivity of the projected gaps to various changes in the uncertain parameters using simple "What-if Analysis" tools contained in Microsoft Excel. This is illustrated in Table 29, which shows the impact of changes in the inflation rate and the rate of change of annual revenues to the present value of the projected gap for the TAMP period. Since this example showed the DOT starting with a balanced budget in 2015, Table 29 shows that the point of inflexion between projected gaps and surpluses is linked to the annual revenue increases keeping pace with inflation.

The "What-if" feature available in Microsoft Excel can be used to prepare sensitivity analyses to demonstrate the impact of changing variables on a desired outcome. In the illustrative example, this Excel feature is used to show the impact on the projected surpluses/shortfalls from changes in both the inflation rate and the annual rate of change in revenues. The results shown in Table 29 illustrate that for a wide range of values of these two variables, the DOT is faced with serious projected funding shortfalls. The DOT leadership will need to consider mechanisms to mitigate the projected shortfalls or make trade-offs, be they within or between programs being implemented by the agency based on priorities, or by sacrificing performance targets included in their plans. These tools can also be used to effectively communicate the projected impact of these risks to stakeholders.

Though the discussion above focusses on financial risks associated with total sources and uses, the same tools and techniques can be used to conduct a variety of "What-if-Analyses". For example, analyses can be performed to evaluate the sensitivity of pavement treatment costs to changes in rates of pavement degradation.

Table 29 Sensitivity of the New Present Value of Projected Gaps during TAMP period to changes in various uncertain parameters (highlighted portions represent base case values for those parameters.)

Sensitivity of Projected Surpluses/(Gaps) to Annual Changes in Revenues and Inflation										
NPV of Projected Surpluses/(Gaps) (2016-2025) in $ Million		Annual Change in Revenues (%)								
		-3.0%	-2.0%	-1.0%	0.0%	1.0%	2.0%	3.0%	4.0%	5.0%
Inflation Rate (%)	3.0%	($2,279)	($1,952)	($1,605)	($1,238)	($849)	($437)	$0	$462	$952
	3.5%	($2,507)	($2,180)	($1,833)	($1,466)	($1,077)	($664)	($228)	$235	$725
	4.0%	($2,742)	($2,414)	($2,067)	($1,700)	**($1,311)**	($899)	($462)	$0	$490
	4.5%	($2,983)	($2,656)	($2,309)	($1,942)	($1,553)	($1,141)	($704)	($241)	$249
	5.0%	($3,232)	($2,904)	($2,557)	($2,190)	($1,801)	($1,389)	($952)	($490)	$0

Incorporating Randomness in Uncertain Variables

As noted in Table 27, the expert panel had recommended ranges for variability in inflation and revenue sources with equal probability of occurrence. The evaluations and presentations described above were based on deterministic values, in that projections were based on specific values identified by the expert panel in its base case recommendations, with outer limits established by the ranges. Even in the sensitivity tables, the impact was computed on the assumption that the variables would vary at the specified rates during the entire plan period. In other words, annual variability was not accounted for.

Incorporating the effects of annual variability is very important because the successful de-

livery of any TAMP plan requires that the agency deliver its planned program of projects systematically year after year. To do this, agency leadership will need to have confidence in the projections of Sources and Uses for every year of the TAMP period. Although the assumption of a uniform probability distribution is somewhat simplistic, a brief explanation is provided here to help set the stage for more detailed description of stochastic tools that incorporate more realistic estimates of annual variability.

Microsoft Excel provides random number generator functions that can be used to generate random numbers within specified limits using a uniform probability distribution that would be representative of the panel recommendations of changes in uncertain parameters with equal probability of occurrence. The computations described in the previous sections can be modified to use randomly variable values of inflation and annual revenue changes, to compute the projected Sources and Uses for the plan period. Each iteration of such a computation will yield different randomly generated values of the uncertain variable. Figure 41 shows the results of one such iteration – with the lines depicting the Sources and Uses and the relevant uncertain variable being shown as bars. Note that the rates of inflation and the annual rate of change in total revenues do not follow a steady and linear trend, but vary randomly from year-to-year. The resultant impact to the projected Sources and Uses is reflected in the chart.

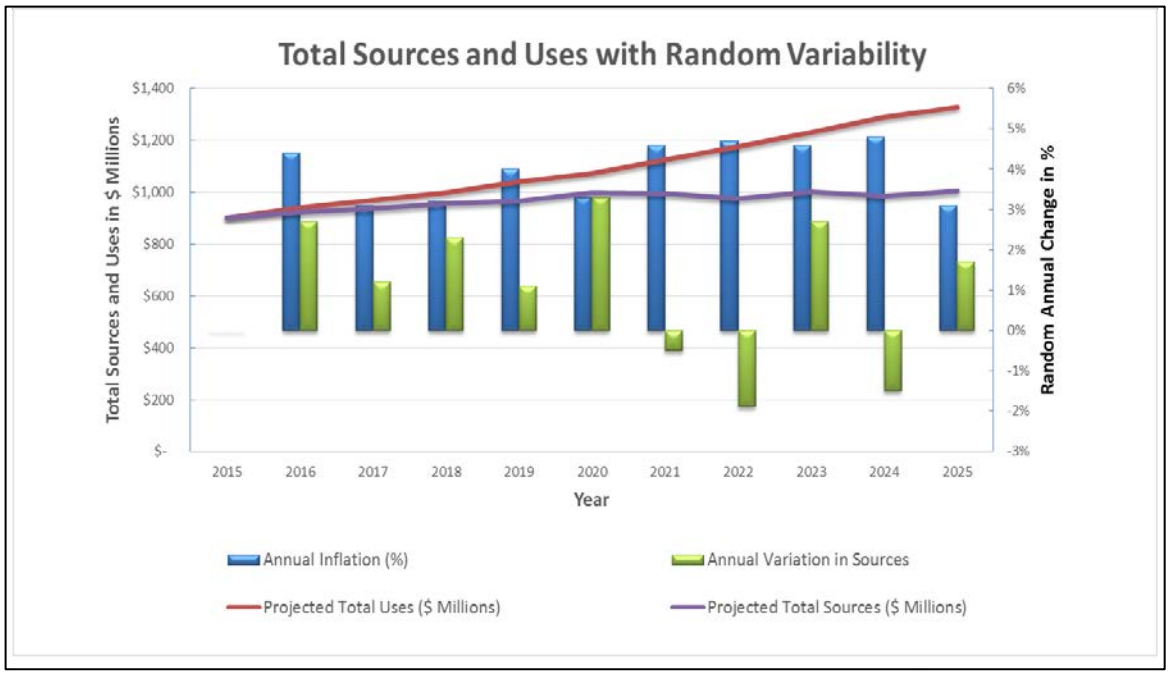


Figure 41 Chart showing the results of one iteration of Projected Sources and Uses using randomly generated values of the uncertain variables within the ranges recommended by the Expert Panel during the TAMP Period.

The differences between the deterministic computations using the base case values and one iteration of the randomly generated values shown in Figure 41 can be seen in Figures 42 and 43 for the Total Sources and Uses, respectively. As can be seen in Figure 42, the specific iteration depicted in the figure projects that the Total Sources in 2025 will be about the

same as that projected using the base case assumptions, but that in the interim period, they are likely to exceed the amounts computed using the base case assumptions. A different iteration using the randomly generated values may yield very different results. The same pattern can be seen in Figure 43 which shows the results of one iteration for projected Uses. This particular iteration shows that the random inflation values project a higher amount of Total Uses by 2025. Projected values of Gaps will similarly show varying values from year to year and the trend will change with each iteration.

The results of any single iteration are therefore of limited use to agency decision-makers because each iteration is equally probable as the next and the DOT will not be able to rely on the results of any single iteration to use as projected values for its TAMP. However, if large numbers of iterations are performed and the results plotted, it is likely that they will show a pattern whereby a majority of the projections may fall within a certain range. An agency might then be in a better position to estimate its level of confidence in the projections made.

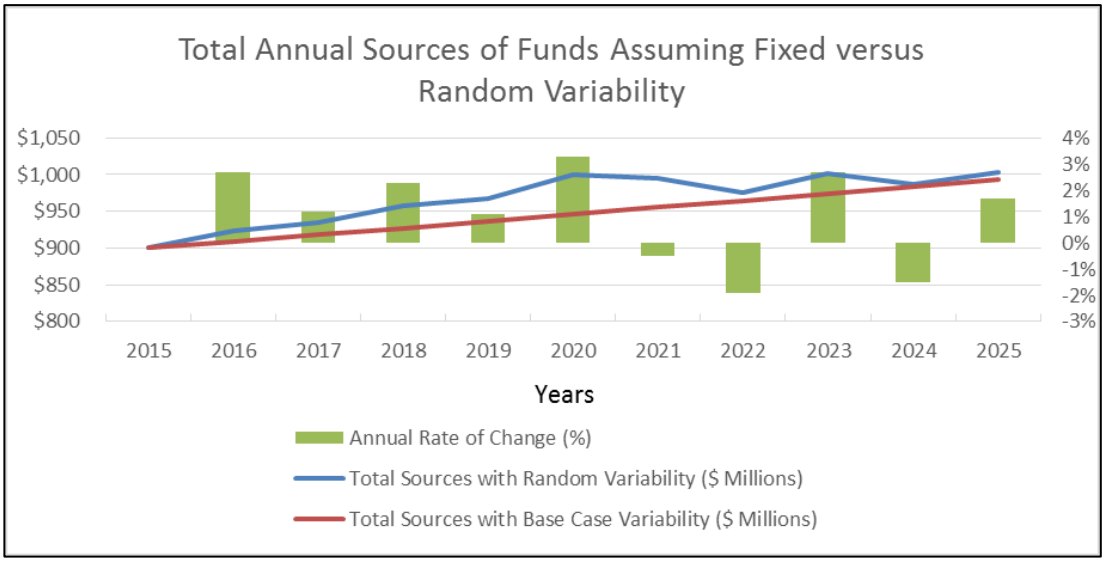


Figure 42 Comparison of the results of one iteration of Projected Sources using random annual variability with the projections using Base Case variation as recommended by the Expert Panel.

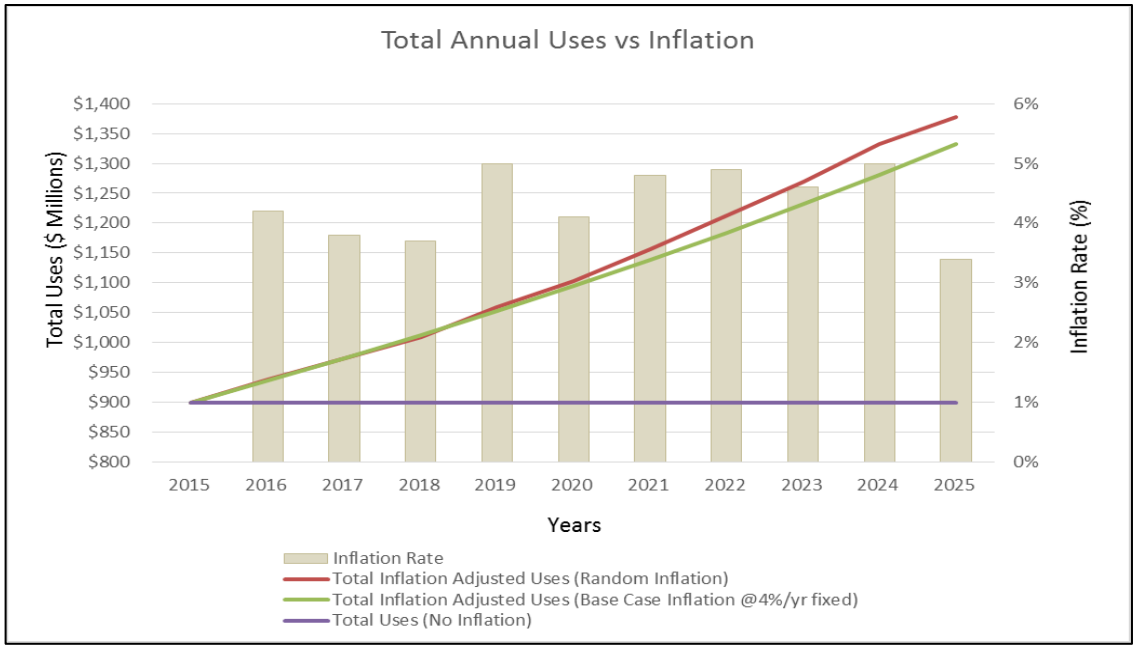


Figure 43 Comparison of the results of one iteration of Projected Uses using random annual changes in inflation with the projections using Base Case inflation as recommended by the Expert Panel.

It is unlikely that any of the variable parameters will follow a uniform probability distribution as illustrated in the simplistic example described above. Tools incorporating more sophisticated stochastic methods can provide additional functionality. As described earlier, such stochastic methods allow not only for estimating the confidence intervals of various projections, but also for using various probability distributions for uncertain variables.

Stochastic Methods – Monte Carlo Simulations

A common analytical tool used to analyze business risk where significant uncertainty is involved is the Monte Carlo simulation. A Monte Carlo simulation uses repeated random sampling in a computational algorithm to compute results. The large number of iterations helps provide increased confidence in the computed results and are particularly useful where probability distributions need to be utilized because of the inherent unpredictability of input variables.

Several online tools are available as add-ins to Microsoft Excel to perform Monte Carlo simulations. These vary in complexity from simple, customizable algorithms to paid, commercially available, add-ins to Microsoft Excel. Since a large quantity of data will likely be used in the analysis process, additional functionalities for distribution fitting of available data may need to be added to what already may be available within Excel. If an agency wishes to customize an algorithm for its internal use, it may need to use a distribution-fitting add-in. Online searches may yield different choices for examples of customizable algorithms. An example of such a customizable algorithm can be found on Vertex42.com. Commercial packages available for purchase in the form of Microsoft Excel add-ins, such as Risk Solver, @Risk, Risk Analyzer, Crystal Ball, Risk AMP, etc., incorporate the necessary

functionalities including distribution fitting within the software to enable risk analysis using Monte Carlo methods.

Key information relating to Monte Carlo simulations, with a focus on the use of online tools, is summarized in this section by using an illustrative example.

Illustrative Example

The illustrative example utilizes 30 years of past history of available Sources and Uses of funds for an example DOT. The example considers eight primary variables for uncertain input parameters. Five of these variables pertain to the annual rate of change of the different sources of funds for the agency, namely, state, federal, local, turnpike and bonds. Three variables have been considered for the annual rate of change of the different uses of funds for the DOT. These pertain to (i) Capital Assets, (ii) Safety, Transit and Projects, and (iii) Operations & Maintenance and Administrative costs. Users can easily modify this example to add or reduce the number of input variables. Projections of future sources and uses for the TAMP period are computed using the historical data, with the assumption that the annual rate of change of various sources and uses will continue to fit within historical distribution patterns observed for these variables, i.e., the agency leadership does not envision any special circumstances, such as new limited-duration funding sources or one-time costs or costs relating to special projects. Such special circumstances, if known or anticipated, will need to be separately accounted for.

As a first step, the historical data would need to be analyzed to identify if the data fits any specific or known probabilistic pattern. This can be done by using distribution fitting tools available through add-ins to Excel. Once the best fit probability distribution is identified, that distribution can be used to predict future values. Several distribution fitting tools, such as, EasyFitXL, XLStat, Sigmamagic.com, etc., including those built into commercial risk analysis software can be utilized for this purpose. For simplicity, the stochastic analysis performed in this example assumes that each variable conforms to a normal distribution. Users can change this assumption to other distributions as appropriate to their data.

The analysis described here uses a simple algorithm for a simulator to predict future values for the TAMP period for each of the eight categories for the sample DOT. This was done by creating a model and simulator for the sample DOT. As described previously, several online sources can be used by a user to create customizable algorithms. Samples and templates can also be downloaded free or for a nominal cost from various online sites.

Historical data for 30 years for a DOT were analyzed for each of the eight categories identified above to determine the annual rate of change for those categories. Future values for each of these variables (five categories related to sources and three categories to uses) were computed for a ten-year TAMP period. In addition, the projected gaps between the sources and uses – whether surpluses or deficits, were computed along with the net present value (NPV) over the TAMP period. For comparison, the example analysis presents the results of both a deterministic computation of the projected ten-year gap (using the historical mean values of the variables) and a stochastic computation (using probability distributions for the variables over 5000 iterations) that incorporates the effect of uncertainty.

Results from a Customized Simulator

Table 30 summarizes the rate of change of the various uncertain input parameters as observed from 30 years of historical data.

Table 30 Rate of change in various categories of uses and sources based on 30 years of historic data.

RATE OF CHANGE OF USES		
Description	Mean	Std Dev
Capital Assets	9.0%	34.2%
Safety, Transit, Projects	10.6%	20.3%
O&M + Admin	6.6%	7.6%

RATE OF CHANGE OF SOURCES		
Description	Mean	Std Dev
State Sources	8.6%	19.1%
Federal Sources	8.5%	14.6%
Turnpike	7.9%	13.8%
Local Funds	8.5%	14.5%
Bonds	8.9%	14.3%

The historical mean values of the rates of change were used as nominal values of these parameters to compute projected sources and uses for the TAMP period (the deterministic estimates). Assuming a normal distribution for the historical rates of change, stochastic projections were also computed. Table 31 provides a summary of the deterministic and stochastic values from only one of the 5,000 iterations. The sources and uses for 2015 were the historical values and were used as a starting point for the computations. The net present values were also computed for each of these categories for the 10-year period. As seen from Table 31, the net present value of the total uses determined by assuming that the historical means adequately represented the anticipated annual rates of change for the various categories is $125,846 million (approximately $125 billion), with annual values ranging from $10 billion in 2015 to $24 billion in 2025. One of the 5000 iterations performed estimated the net present value to be nearly $266 billion. Similarly, the deterministic value of the total sources was $124,485 million (approximately $124 billion) as compared to a stochastic estimate of $141 billion. Pressing the “F9” function key populates new values in the table from the stochastic computations, each representing the results of another iteration. Each iteration will compute values that may be at significant variance from those in another iteration. For example, the Capital Assets vary from $5 billion in 2015 to $704 million in 2025 in the iteration shown in Table 31. A different iteration may yield different values from these. Repeating the iterations and capturing the results of each iteration allows the tabulation of a large number of computations using the assumed probability distribution. The computed results will show a convergence of values with a higher probability of occurrence around certain expected values. Using formulas available in Excel, the frequency of occurrence of various results within certain ranges (bins) will allow the determination of the probability of occurrence of those values and several other statistical parameters that decision makers can use to identify confidence intervals and subsequently get comfortable with the projections they wish to use within the limits of their levels of risk

tolerance.

Table 32 summarizes the results of 5000 iterations using stochastic methods. It is seen that the values computed in the single iteration represented in Table 31 showed a projected deficit over 10 years of nearly $125 billion, with a probability of occurrence of 41.4%, whereas the mean value of the stochastic projections showed a projected surplus of approximately $14 billion with a probability of 48%. The stochastic methods project a 59% probability that there will be a surplus over the TAMP period for this sample DOT. By contrast, the deterministic computation projected a deficit of approximately $1.3 billion.

Table 31 Estimated values of the various sources and uses over the 10-year TAMP period using deterministic and stochastic (one iteration) methods.

PROJECTIONS - DETERMINISTIC AND STOCHASTIC ($, Millions)												
NOTE: Although the EasyFitXL Add-in Tool showed different distributions as the best fit for the various parameters above, for simplicity, the stochastic computations below assume a Normal Distribution for the rate of change.												
PROJECTED USES	**NPV**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Nominal Values ($ Millions)												
Capital Assets	$63,117	5,099	5,559	6,062	6,610	7,207	7,859	8,569	9,343	10,188	11,109	12,113
Safety, Transit, Projects	$48,466	3,603	3,985	4,407	4,874	5,390	5,961	6,592	7,290	8,063	8,916	9,861
O&M + Admin	$14,263	1,311	1,398	1,490	1,588	1,693	1,805	1,924	2,051	2,186	2,331	2,484
Total Projected Uses	$125,846	10,013	10,942	11,959	13,072	14,291	15,625	17,085	18,685	20,437	22,356	24,458
Stochastic Values (Normal Distribution) from Single Iteration												
Capital Assets	$22,423	5,099	$5,523	$4,294	$3,406	$2,030	$1,543	$2,036	$1,582	$1,322	$1,004	$704
Safety, Transit, Projects	$232,761	3,603	$3,770	$3,826	$4,813	$3,923	$5,108	$6,427	$7,229	$7,801	$7,776	$7,876
O&M + Admin	$10,755	1,311	$1,554	$1,524	$1,683	$1,645	$1,669	$1,717	$1,712	$1,803	$1,937	$2,061
Total Projected Uses	$265,939	10,013	10,846	9,644	9,902	7,598	8,319	10,179	10,522	10,926	10,717	10,641
PROJECTED SOURCES	**NPV**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Nominal Values ($ Millions)												
State Sources	$71,748	5,740	6,236	6,776	7,362	7,998	8,690	9,442	10,258	11,145	12,109	13,156
Federal Sources	$30,843	2,490	2,701	2,929	3,177	3,446	3,738	4,054	4,397	4,769	5,173	5,611
Turnpike	$9,411	782	844	910	982	1,059	1,142	1,232	1,329	1,434	1,547	1,669
Local Funds	$9,924	800	868	942	1,022	1,108	1,203	1,305	1,416	1,536	1,666	1,808
Bonds	$2,560	202	220	240	261	284	310	337	368	400	436	475
Total Projected Sources	$124,485	$10,014	$10,869	$11,796	$12,803	$13,896	$15,082	$16,370	$17,768	$19,285	$20,931	$22,718
Stochastic Values (Normal Distribution) from Single Iteration												
State Sources	$77,769	5,740	5,120	5,121	4,476	4,356	4,934	4,281	5,838	6,794	9,022	11,310
Federal Sources	$18,916	2,490	$3,001	$3,072	$2,703	$2,521	$2,526	$1,851	$2,284	$3,050	$3,478	$3,531
Turnpike	$12,423	782	$839	$830	$855	$827	$752	$878	$1,044	$1,258	$1,491	$1,790
Local Funds	$28,480	800	$650	$858	$702	$808	$657	$715	$1,018	$1,062	$1,155	$1,115
Bonds	$3,649	202	$235	$292	$396	$412	$569	$639	$624	$621	$716	$615
Total Projected Sources	$141,238	$10,014	$9,844	$10,173	$9,132	$8,924	$9,438	$8,364	$10,808	$12,786	$15,862	$18,361

Table 32 Summary results showing the computation of the NPV of the projected gaps along with the probability of occurrence of the computed stochastic values.

Projections for Sources, Uses and Gaps using Monte Carlo Simulation ($, Millions)				
Uncertain Inputs Variables	**Probability Distribution* for Uncertain Inputs**	**Deterministic Value of 10-Year NPV** (using nominal values of input parameters)	**Nominal Value of Rate of Change (Hist Mean)**	**Stochastic Value of 10-Year NPV** (from Single Iteration)
Sources of Funds				
State Sources	Normal	$71,748	8.6%	$77,769
Federal Sources	Normal	$30,843	8.5%	$18,916
Turnpike	Normal	$9,411	7.9%	$12,423
Local	Normal	$9,924	8.5%	$28,480
Bonds	Normal	$2,560	8.9%	$3,649
Total Sources		**$124,485**		**$141,238**
Uses of Funds				
Capital Assets	Normal	$63,117	9.0%	$22,423
Safety, Transit, Projects	Normal	$48,466	10.6%	$232,761
O&M + Admin	Normal	$14,263	6.6%	$10,755
Total Uses		**$125,846**		**$265,939**
Discount Rate for NPV Computations			5%	

* Normal Distribution assumed for simplicity

Monte Carlo Simulation Results				
Description		**Deterministic**	**Stochastic**	
			(Single Iteration)	(Mean Value of Gap)
Present Value of Total Sources (2015-2024)		$124,485	$141,238	
Present Value of Total Uses (2015-2024)		$125,846	$265,939	
Gaps (Sources - Uses)	**Projected Value**	**-$1,361**	**-$124,701**	**$14,352**
	Probability		**41.40%**	**48%**

Summary Statistics for Present Value of Projected Gaps for 10 Years	
Probabilities	
Probability of Projected Surplus (Gap > 0):	**59%**
Probability of Projected Deficit (Gap < 0):	**41%**

Figure 43 shows a histogram of the net present value of projected funding gaps from the Monte Carlo simulation. A chart of the cumulative probability is also shown in this figure. Note that extreme values of projected gaps exceeding (in the case of surpluses) or less than (in the case of deficits) $250 billion were considered to be outliers and ignored.

All of the information presented in this example can be prepared using readily available features in Microsoft Excel and through the use of online and customizable templates and add-ins. If the stochastic projections predicted a high probability of deficits over the TAMP period, the agency will need to plan various strategies to deal with such an eventuality. Information prepared using such tools can allow the agency to communicate with decision-makers and others who can assist in addressing deficits if those were to happen. It also allows the agency to implement various strategies that may be pertinent to the state's situation. Presenting such information can also augment the strategies that agencies use to get the buy-in and support from the appropriate influencers and decision-makers for proactive

preservation and maintenance strategies.

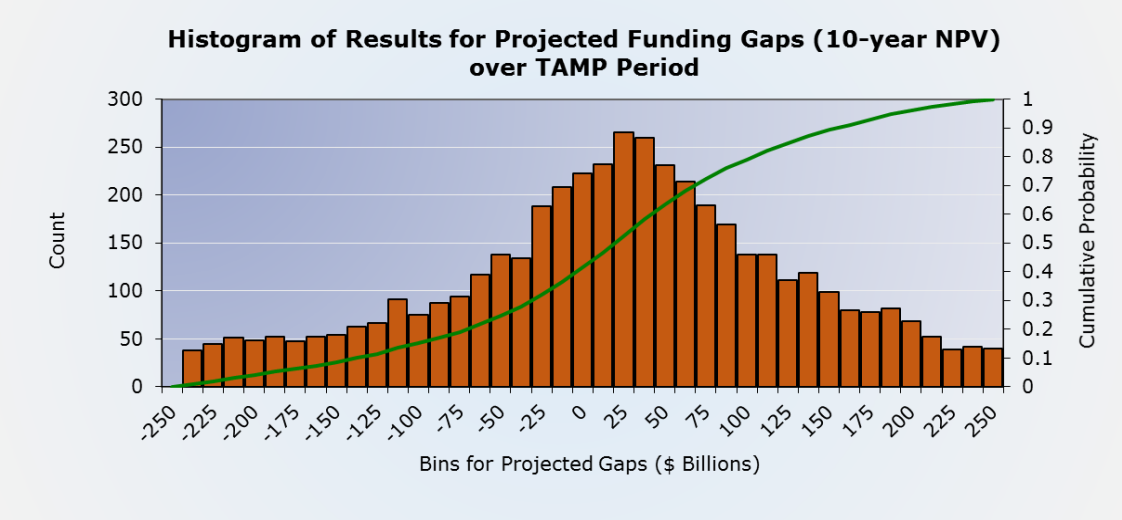


Figure 44 Histogram of projected funding gaps using Monte Carlo simulation.

Commercially Available Software

Several other commercial tools are available to add functionality to the Monte Carlo Simulations. They vary in degree of complexity, functionality and price. The following description uses one such tool called @RISK from Palisade that adds to Microsoft Excel and provides more functionality in the Monte Carlo simulation to data models. It is to be noted that this report is not endorsing or recommending any one product over the other, but simply illustrating a few options that are available in the marketplace. Users should conduct their own evaluations of the available products and decide what best fits their needs and circumstances. The @RISK software illustrated in the following example has more enhanced features compared to the tools discussed earlier. These include a distribution fitting tool, which will suggest the distribution based on the best fitting of the data being analyzed. It has a more automated setup to perform iterations and has other features to define inputs and outputs. It also has several features that allow users to present the data using different distributions. There also are options for a variety of output reports and graphical representations that can provide useful data analytics for decision makers.

In the following example, the historic rates of change of various categories of uses based on 30 years of data are used to project the distribution of the funds needed by a sample DOT for the upcoming 10-year period (2016-2025). The rates of change of funds used in the following categories are computed from the historical data (Table 33):

1. Pavements
2. Bridges

3. Operation and Maintenance
4. Administrative

Table 33 Historical rates of change for various uses for a sample DOT.

Historical Rate of Change																	
	Mean	Std Dev	1983	1984	1985	1986	1987	1988	1990	1991	1992	1993	1994	1995	1996	1997
Pavements (Total Including Turnpike)	0.15	0.72		0.01	0.37	-0.45	(0.41)	(0.46)	3.90	0.24	(0.04)	0.51	(0.03)	(0.13)	0.09	0.08
Bridges (Total Including Turnpike)	0.19	0.73		-0.76	3.52	-0.33	0.18	0.25	0.47	(0.43)	0.78	0.57	(0.13)	0.52	(0.27)	0.20
Operation and Maintenance (all)	0.36	1.74		0.06	0.11	0.21	0.12	0.07	0.16	0.01	0.10	0.10	0.12	0.01	0.05	0.05
Admin	0.07	0.15		0.20	0.25	0.41	(0.03)	(0.12)	0.38	0.21	0.26	(0.08)	0.11	0.05	0.06	(0.08)
Total Uses				-0.12	0.42	-0.12	(0.02)	(0.00)	0.54	0.00	0.16	0.26	0.02	0.07	(0.02)	0.07
		NOTE:	In determining the distributions, the outliers in the yellow-highlighted cells above were excluded.													

Historical Rate of Change																	
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Pavements (Total Including Turnpike)	0.02	0.23	(0.10)	0.12	0.13	0.13	0.37	0.08	(0.31)	0.03	(0.10)	0.07	(0.10)	0.00	(0.13)	0.40	0.02
Bridges (Total Including Turnpike)	(0.17)	0.50	(0.34)	(0.37)	1.00	0.24	(0.70)	0.39	0.54	(0.02)	(0.04)	0.46	(0.00)	(0.01)	(0.26)	(0.10)	0.05
Operation and Maintenance (all)	0.07	0.02	0.05	0.07	0.05	0.02	0.06	0.20	0.02	0.03	0.20	(0.01)	(0.91)	9.81	(0.03)	0.24	(0.04)
Admin	(0.20)	0.29	(0.03)	(0.02)	0.05	0.04	(0.09)	0.08	0.01	(0.07)	(0.04)	0.07	(0.21)	0.07	0.11	0.04	0.09
Total Uses	(0.03)	0.20	(0.10)	(0.01)	0.19	0.10	(0.03)	0.15	(0.08)	0.01	0.05	0.08	(0.49)	0.82	(0.09)	0.21	(0.01)

Table 34 Statistical parameters with and without outliers.

	Mean (exclude outliers)	Std Dev.(Exclude Outliers)	Mean	Std Dev
Pavements (Total Including Turnp	0.03	0.23	0.15	0.72
Bridges (Total Including Turnpike)	0.08	0.42	0.19	0.73
Operation and Maintenance (all)	0.08	0.07	0.36	1.74
Admin	0.07	0.15	0.07	0.15
Total Uses				

Table 35 Selection of distributions for uncertain input variables.

Uncertain Inputs	Excluding outliers and fixing the bounds	
Description	Rate of Change from Distribution	Distribution Used
Pavements	0.25	Triangular
Bridges	0.25	Triangular
O&M	0.07	Triangular
Admin	0.08	Triangular
Total	0.11	Triangular
Discount Rate	0.04	Triangular

=RiskTriang(-0.49,-0.0061426,0.82,RiskName("Rate of Change - Total Costs"))

Table 36 Snapshot of results from one iteration for various categories of projected uses.

	Snap Shot of Results from One Sumulation using 5000 Iterations (NOTE: 2015 Data is Actual; 2016-2025 are projected values for Illustrative purposes only)										
Item Description	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
10-Year Pavement Costs (2016-2025)	$ 648	812	1,018	1,276	1,599	2,004	2,512	3,148	3,946	4,210	4,834
10-Year Bridge Costs (2016-2025)	$ 245	305	380	474	591	737	919	1,146	1,428	1,781	2,220
10-Year O&M Costs (2016-2025)	$ 1,119	1,194	1,274	1,358	1,449	1,546	1,649	1,759	1,876	2,001	2,134
10-Year Admin Costs (2016-2025)	$ 156	169	182	197	213	231	249	270	291	315	341
10-Year Total Uses (2016-2025)	$ 2,168	2,480	2,854	3,306	3,852	4,517	5,329	6,322	7,541	8,306	9,529

Table 37 Comparison of deterministic versus stochastic projections.

Comparison of Deterministic Vs Stochastic Projections						
Item Description	**Projected Present Values at a fixed Discount Rate of 4% (Deterministic Value)**	**Stochastic Projections**				
		Projected Net Present Value (10 Year)	**Probability of Occurrence of Projected Value***	**Mean Value of Projection**	**Probability of Occurrence of Mean***	**Median Value of Projection (50% Probability of Occurrence)**
NPV of 10-Year Pavement Costs (2016-2025)	20,792	$ 20,335	50.60%	$ 23,949	61%	$ 20,161
NPV of 10-Year Bridge Costs (2016-2025)	7,569	$ 7,404	45.50%	$ 29,035	71%	$ 9,673
NPV of 10-Year O&M Costs (2016-2025)	12,899	$ 12,666	55.30%	$ 13,481	61%	$ 13,255
NPV of 10-Year Admin Costs (2016-2025)	1,944	$ 1,908	53%	$ 2,455	65%	$ 1,827
NPV of 10-Year Total Uses (2016-2025)	43,205	$ 42,314	31.50%	$ 68,921	67%	$ 54,001

*NOTE: Probability Values represent the probability that the value will be less than or equal to the projected value

Evaluation of the historical data indicated that in a few instances (shown in yellow highlights in Table 33), significant changes had occurred. These likely represent special circumstances for those specific years and are not representative of long-term trends. Since the projections specifically exclude special circumstances, these yellow highlighted items were considered to be outliers and excluded from the computations of mean and standard deviation (Table 34).

To illustrate the use of the software tool, it can be used to obtain a recommendation on the best fit distribution for the rates of change in the above mentioned four categories. The tool provides options that allow users to indicate if the upper and lower limits of the rate of change are “bounded”, “fixed” or “unsure”. Based on the option chosen for the upper and lower limits, the software will recommend various distribution fits. There is also an option that will allow the suppression of questionable fits. Based on these selections, a list of distribution fits is presented to the user to select. The best fit distribution recommended by the software was a “Triangular” distribution for both the “Operation and Maintenance” and for the “Admin” categories. Users can change the recommended distribution and select from several other distributions. This option is important because the circumstances and projections for the future can be influenced by many other factors that are not captured in past data trends. For simplicity, a “Triangular” distribution was used for all four input variables that are associated with the Uses (See Table 35).

Table 36 shows the projected uses in the various categories along with the Total Uses from one iteration (out of 5000 iterations completed during the simulation) for the 10-year TAMP period. It is important to recognize that individual iterations (such as the values in the example shown in Table 36) may generate values that may not be representative of the values with the highest probability of occurrence. The value of the stochastic analyses comes from repeating the computations over a large number of iterations, such that the values with the highest probabilities of occurrence can be determined.

The NPV of the projected Uses for the 10-year period are shown in Table 37 - both the deterministic values using the historic mean value of the rate of change and the stochastic values generated by the tool from 5000 iterations are shown. The mean and median values from the simulation, and the probabilities of occurrence of the projected value and the mean value are also shown. In the deterministic computations of the NPV, a discount rate of 4% has been used. For the stochastic projections, random variability of the discount rate was also considered. A “Triangular” distribution with the variability between 3% and 6% (lower and upper bounds) was assumed for the discount rate. As stated earlier while discussing the Delphi technique, based on expert judgment or other specific information or circumstances, users can select a distribution that is most appropriate to their example. It can be seen that the mean value indicates an aggregate amount of Total Uses of approximately $69 billion over the TAMP period with a probability of occurrence of 67%, whereas the deterministic value estimated a lower amount of $43 billion. The results of one iteration showing projected Uses of $42 billion had a much lower (31.5%) probability of occurrence, indicating that the deterministic value also would have a similar probability of occurrence. The utility of the analysis and the use of such tools is therefore evident from these results.

The tool also provides options that allow users to present the data in the form of charts. Figure 44 contains one of the output chart formats which indicates a 73% probability that

the NPV of pavement needs will be between $9.8 billion and $38 billion, i.e., one standard deviation above and below the mean value of $23.9 billion. Figure 45 also shows that in this example, there is only a 15.3% probability that the NPV of the Pavement needs for the 10-year period will exceed $38 billion. A variety of statistical information from the simulation is

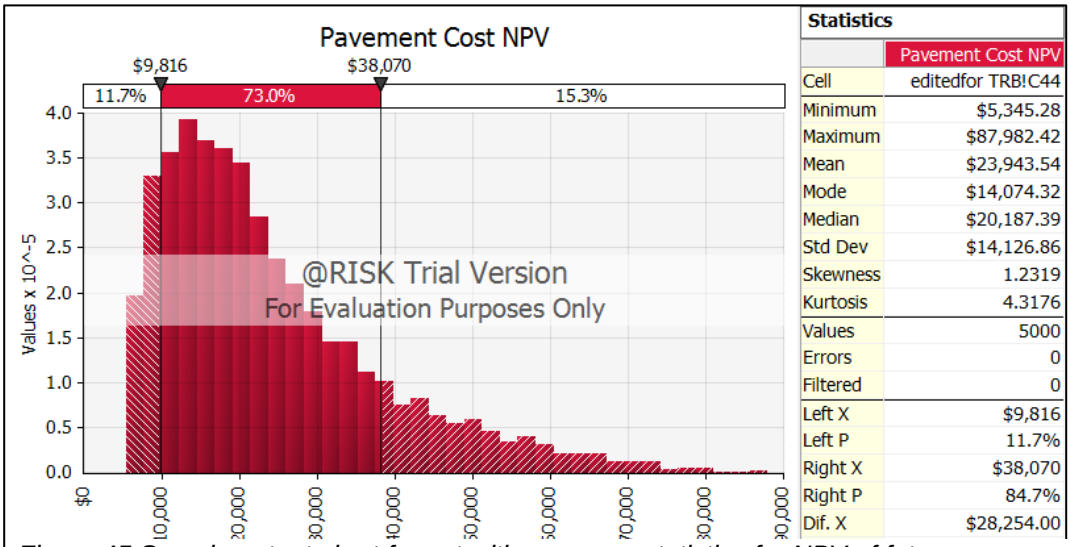


Figure 45 Sample output chart format with summary statistics for NPV of future pavement costs.

also summarized adjacent to the chart.

Another useful output chart format is illustrated in Figure 47. This chart format, called a "Tornado" chart, illustrates the relative impact of the various uncertain input variables on the mean values projected using the Monte Carlo Simulation. In the current example, it shows that the annual rate of change of bridge costs has by far the biggest impact on the output mean followed by the rate of change of pavement costs. Other variables are shown to have a smaller impact. This provides valuable information to agency decision makers

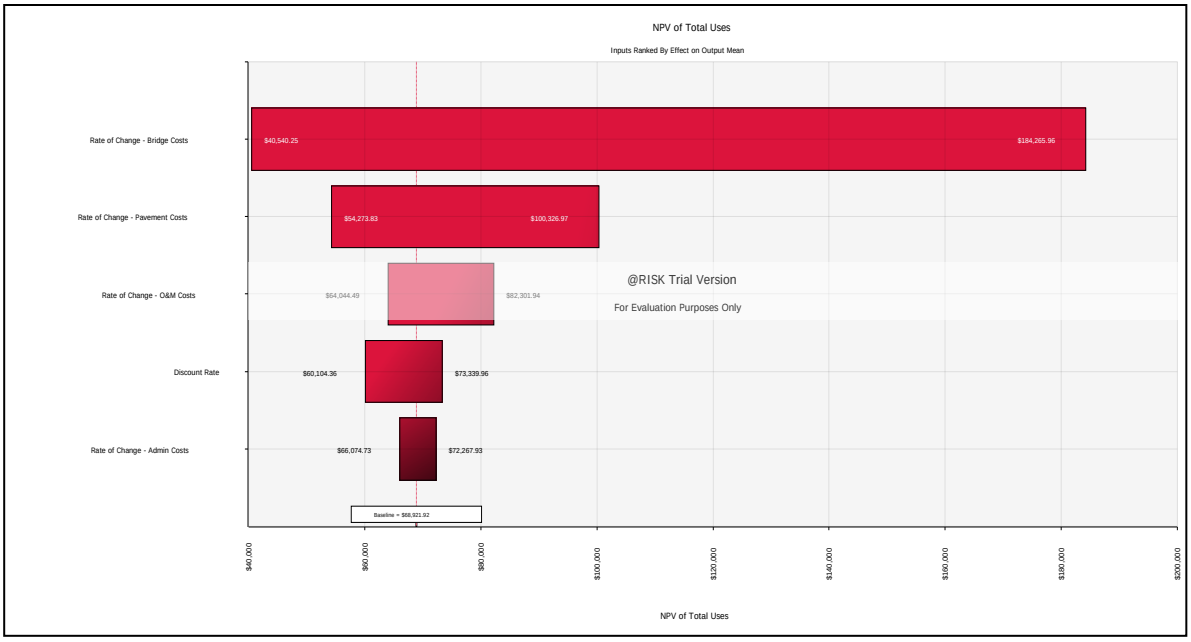


Figure 46 Tornado chart showing the relative impact of various uncertain inputs on the simulation results.

which they can use to control their program budgets.

Monte Carlo simulations have been successfully used in several instances in transportation applications. For example, it has been used to analyze transportation project risks associated with Public-private-partnerships (P3) involving the evaluation of retained, transferred and shared risks prior to pursing P3 options[188]. Another example involves the use of a Monte Carlo analysis in the Portsmouth Bypass FHWA Cost Estimate Review by the Ohio DOT and FHWA to establish the project cost estimates and related confidence intervals after accounting for project risks[189].

Other Tools to Facilitate Decision Making

A "Decision Tree" is another tool that can be very useful in making decisions when agencies are faced with uncertainties. Investopedia defines a Decision Tree as follows:

"A schematic tree-shaped diagram used to determine a course of action or show a statistical probability. Each branch of the decision tree represents a possible decision or occurrence. The tree structure shows how one choice leads to the next, and the use of branches indicates that each option is mutually exclusive."

Decision Trees are useful when decisions involve selecting one of multiple paths or branches, each of which are mutually exclusive. The selection of each branch or path can lead to zero or more additional paths that are mutually exclusive. A Decision Tree is the pictorial representation of these paths and the implications in the form of a tree with branches. The end of each path is a final branch. The final branch shows the result of selections that lead to that final branch. By following the different branches, users can see the implications of the different options. Each option or branch may have different costs and different probabilities of success.

There are several free and commercial tools available to create Decision Trees. A simple internet search showed several simple and complex tools that support Decision Trees. Several of these are add-ins to Excel. Tools that are Excel add-ins include,

1. SolutionTree
2. TreePlan
3. PrecisionTree

They are so common that YouTube provides many examples of how to create Decision Trees.

The important aspect of using these and other tools is understanding how to use the tool for the analysis of specific subject areas. The following is an illustration on using TreePlan, an Excel add-in, to create a Decision Tree. Decision trees allow users to analyze mutually exclusive sequential events that have some uncertainty. The scenario described below addresses the choices available to an agency when faced with a decision of whether to perform a geotechnical study to address and fix a potential slope failure, the probabilities of success of various options, and the associated costs. The Decision Tree prepared to evaluate these options is illustrated in Figure 47. Each decision point is represented in the tree by a square node, while each potential outcome is represented by a circular node. Figure

47 shows that there are two likely decision points, with three sets of mutually exclusive outcomes, each with an associated probability of occurrence. These probabilities allow the agency to address the risk or uncertainty of those outcomes.

The first decision point is whether to perform a geotechnical study which is expected to cost $50,000. By following all the logical outcomes of each possible decision in the tree using probability-adjusted costs, the agency can arrive at probability-adjusted costs of whether or not to conduct the study and make a choice that results in the least cost. Figure 48 shows that if the agency does not perform the geotechnical study, it would save $50,000, but it would not know if and when the slope may fail. The agency has identified that if it chooses not to perform the study and leave the slope as is, and the slope does eventually fail, it will not have recourse to remediation options (since it would not have taken timely preventative action) and will have to rebuild the slope costing it $350,000. The agency has also estimated that if it chooses not to take any action, there is an 85% chance that the slope might fail. This implies that there is a 15% chance that the slope might not fail, in which event the total cost to the agency would be zero. The probability adjusted cost of deciding to not perform the geotechnical study based on the potential outcomes is thus $297,500 ($350,000 X 85% + $0 X 15%).

On the other hand, if the agency does perform the geotechnical study, there is a 65% chance that it might identify the potential for slope failure, at which point it can either remediate or rebuild the slope. This presents another decision that the agency has to make. The cost of remediation is $100,000, whereas the cost of rebuilding is $300,000. The obvious choice at this point would appear to be remediation, but the agency recognizes that remediation may or may not succeed, with an 80% probability of success. Up to this point, the agency would have only spent $50,000 in conducting the geotechnical study. If it chooses to remediate and the remediation is successful, it would eventually incur a total cost of $150,000 ($50,000 + $100,000). If the remediation fails, the agency would have to incur an additional $200,000 to fix the slope. This path would result in a total cost of $350,000 ($50,000 + $100,000 + $200,000). Therefore, the probability adjusted cost of the remediation option is computed to be $190,000 ($150,000 X 80% + $350,000 X 20%). This is lower than the cost of rebuilding ($50,000 + $300,000 = $350,000), so the clearly preferable choice is remediation with a probability adjusted cost of $190,000.

The second possible outcome after conducting the geotechnical study (with an estimated 35% probability of occurrence) is that no issues will be found indicating that the agency need not take any further action on the slope. In this case, the total cost to the agency at this point would be just the cost of the geotechnical study, or $50,000.

Hence, the probability adjusted cost of choosing to perform the geotechnical study computed by taking all the mutually exclusive options that follow into consideration, is $141,000 ($190,000 X 65% + $50,000 X 35%). Clearly this cost of $141,000 is lower than the probability adjusted cost of not performing the geotechnical study ($297,500) and would therefore be the preferable option. The Decision Tree would therefore point the decision in favor of performing the study.

It is seen that the probability adjusted costs, which account for the uncertainty of subsequent mutually exclusive outcomes, computed at each of the two decision points allow the agency to make clear choices. By following the tree and assessing the potential probability adjusted cost at each decision point, the agency would choose to remediate the slope.

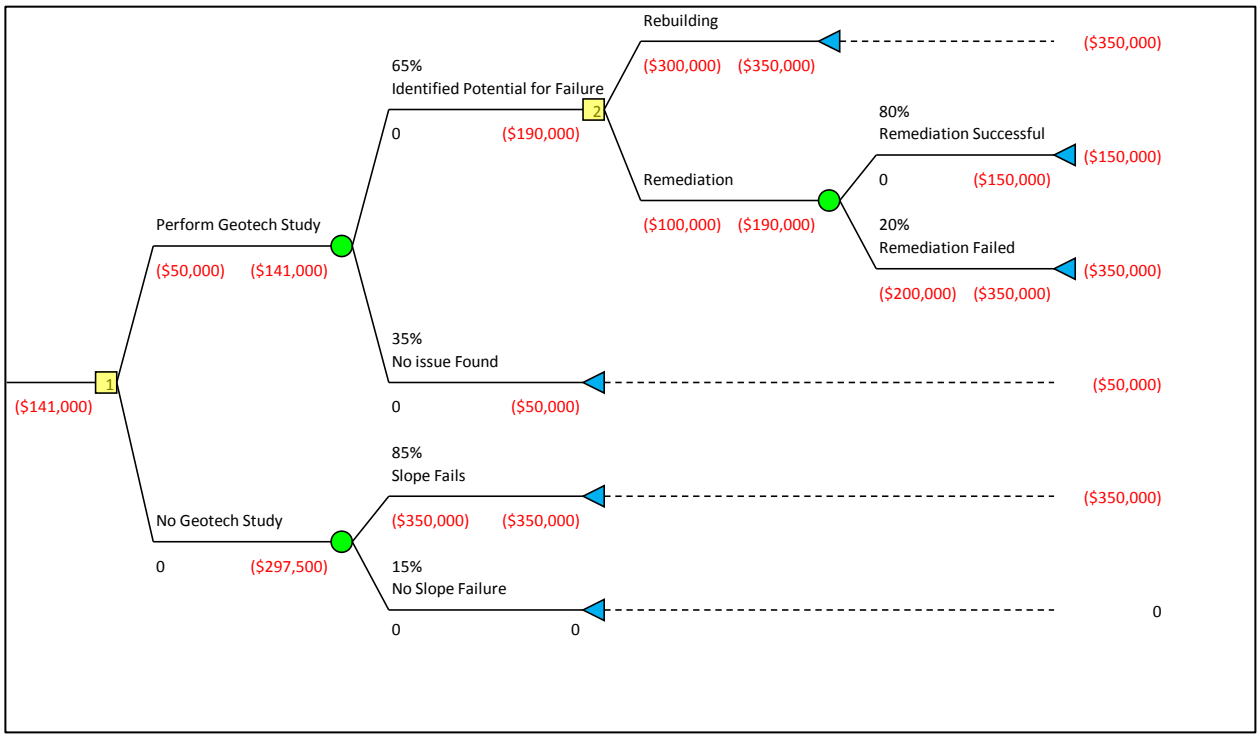


Figure 47 Decision Tree showing options and potential outcomes with associated probabilities and costs of a decision involving the completion of a geotechnical study.

Selecting the best choice from many sequential events that are uncertain can be complex. The Decision tree tools allow users to map out information about many mutually exclusive sequential choices where each choice can lead to many other mutually exclusive paths, each with various levels of uncertainty. As shown in the example Decision Tree, the tool presents the cost of each path and highlights the most cost effective path based on the probability adjusted value of each path.

Conclusions

Risk management is becoming very important in the current environment where agencies are grappling with funding uncertainties, forecasting conditions of aging assets, and addressing climate change issues. Risk management tools can be effective in presenting the risks surrounding transportation investment decisions to stakeholders. They can be used to present the impacts of items such as, liabilities, deferred costs, and funding gaps on the long-term conditions of transportation assets. They can also be used to present the factors that pose the greatest risk to the agency's long-term plans and investment forecasts.

The tools discussed in this report range in complexity. There are many sophisticated tools that are available in the market place. Several are being used in the private sector for projecting things such as stock price variability, insurance rates and other business risks. How-

ever, simplicity and transparency in risk analysis is important. Simple Excel add-in tools provide transparency that agencies can use to understand the severity and likelihood of various risks, including financial risks. Simple Excel add-ins can serve as the first generation of tools for agencies that are in the early stages of integrating formal risk analysis and management into decision-making. John Milton, Director, Quality Assurance and Transportation System Safety for the Washington DOT explained that his experience working with a complex risk management tool is that it was discontinued because of its complexity and lack of transparency. In a Wall Street Journal online article titled, "Rising Trends in Risk Management, RIMS members tackle new challenges; role broadens", the author Russ Banham quotes the following from Bill Coffin, head of publications for the New York-based Risk and Insurance Management Society (RIMS), a not-for-profit organization: [190]

"Sound risk management requires varied expertise from a lot of different types of people across an organization. There's no one perfect tool to analyze or mitigate any organization's risk. We're seeing risk managers move beyond standardized rating systems and risk models to adopt customized valuation tools that provide the transparency necessary to identify and address the unique nature of risk found in their organizations."

The examples discussed in this report show how such tools can be used for enterprise level risk analysis and project activity level decision making. They can just as effectively be used for a variety of other applications, such as, to analyze risks to project costs and schedules from one or many factors (for example, delayed Right-of-way or utility clearances). Tools such as the Monte Carlo simulator can be used to incorporate probability into the analysis, especially when historic data from within the agency or other agencies are available. Tools may also be used in conjunction with each other. For example, if the stochastic or probabilistic tools are used to evaluate the likely costs (within certain acceptable probability ranges) of mutually exclusive options available to an agency, these data could be used as inputs in a decision-tree tool to make a decision on the best option for the agency to pursue.

Results of analyses can be used by agencies not just to make decisions that address various risks, but also to present the impacts of various choices and investments on the transportation infrastructure to the state's political leadership and other stakeholders. Although the examples illustrated the use of tools in analyzing and addressing financial risks, which are a major area of concern for transportation agencies, they can be used effectively to, among others things:

- Understand and communicate the implications of various trade-offs;
- Illustrate the impact of delayed application of asset treatments;
- Understand and present to stakeholders the risk of 10-year revenue forecasts based on assumptions to State fuel-tax growth, Federal-aid, State fees, and bond income;
- Estimate and present the probabilities of construction-inflation growth rates for long-term capital-expenditure forecasts, such as pavement or bridge programs;
- Illustrate the degree of risk surrounding a pavement-investment forecast such as the amount of investment needed to sustain pavement conditions at a given level for 10 years;
- Illustrate the need for investment in maintenance and the impact of routine maintenance on pavement and bridge performance;

- Forecast the risk of performance failure of low-cost treatments such as chip seals if they are placed on higher-volume roadways;
- Illustrate the highest “expected value” among several risk-based investment alternatives;
- Incorporate and present the recommendation of subject matter experts on the likelihood of climate change and other risks and the impact of decisions made on their transportation infrastructure.

The use of risk analysis tools will bring maturity and quantification to risk-based investment decisions. They will bring consistency in the way information is presented. They will allow public agencies to replicate some of the best risk-based practices from the corporate world. Ultimately, each agency will need to determine the level of complexity it would want to utilize in its formal risk analysis process and implement what it considers to be an appropriate and prudent approach, given its own unique set of circumstances.

Glossary

activity. A coordinated set of ongoing actions that are taken to support projects or programs.

avoid. Not taking a risk by not starting or continuing an activity that gives rise to risk.

chief risk officer. The official charged with leading or coordinating risk management efforts.

communication and consultation. A process of continual and iterative dialog that an organization conducts to provide, share or obtain information and to engage with stakeholders regarding the management of risk.

consequence table. A matrix in which the consequence levels are described.

COSO. The Committee of Sponsoring Organizations' (COSO) is an association of accountants and auditors whose mission is to provide thought leadership through the development of comprehensive frameworks and guidance on enterprise risk management, internal control, and fraud deterrence.

decision trees. These are schematic tree-shaped diagrams used to determine a course of action or show a statistical probability. Each branch of the decision tree represents a possible decision or occurrence. The tree structure shows how one choice leads to the next, and the use of branches indicates that each option is mutually exclusive.

enterprise risk management. The formal and systematic effort to control uncertainty and variability on an organization's strategic objectives by managing risks at all levels of the organization.

expected value. The product of likelihood and consequence.

ISO. The Swiss-based International Organization for Standards.

impact. The resulting effect of something happening.

key risk indicators. Metrics that reflect the value or magnitude of a risk.

likelihood. The estimated potential occurrence of an event. This guide does not use it to be synonymous with probability, which infers some statistical computation. Instead, likelihood could be estimated entirely by the judgment of the participants.

likelihood table. A matrix or table that contains the scale used to assess the likelihood of a risk.

managing risk. A broad range of risk responses including the action, or inaction, consciously taken as a result of identifying, assessing, and prioritizing a risk. In this guide it is used specifically to refer to what other guides call "risk treatment" or "risk response." Some guides use the term of "managing risk" to refer to the entire process of establishing and operating a risk management effort.

mitigate. Actions taken to enact a strategy designed to lower the likelihood, lower the consequence, or both of a threat or an event or circumstance that creates variability.

monitoring and review. Ongoing processes of observing and measuring the risk environment and risk response strategies.

Monte Carlo analysis. An analytic process that uses repeated random sampling in a computational algorithm to compute results.

programs. A group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually.

project. A temporary endeavor undertaken to create a unique product, service, or result.

redundancy. Duplicative or excess capacity that can be used in times of emergency.

residual risk. The risk that remains after a risk has been mitigated.

resiliency. The ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events.

risk analysis. The process to comprehend the nature of risk and to determine the level of risk.

risk appetite. The threshold or tolerance for risk. It can be quantitative or qualitative.

risk evaluation. The process of comparing the results of risk analysis with risk appetite to determine whether the risk and/or its magnitude is acceptable or tolerable.

risk identification. The process of finding, recognizing, and describing risks.

risk. The positive or negative effects of uncertainty or variability on agency objectives.

risk management. The cultures, processes, and structures that are directed toward the effective management of potential opportunities and threats.

risk management process. This is the systematic application of policies, procedures, and practices to the identification and management of uncertainty or variability on achievement of agency objectives.

risk map. A matrix that plots on a horizontal and vertical axis a set of risks after they have been assessed by their likelihood and impact.

risk matrix. A table-like summary that illustrates the product of the consequence and the likelihood in a numeric and/or graphical depiction.

risk owners. The individuals to whom the accountability and authority to manage risks has been assigned.

risk register. A document, usually presented in a table-like format, that summarizes the assessment of a risk and how it is being managed. Risk registers can exist for individual risks, or they can summarize all of an entity's risks.

risk triangle. A graphic developed by an FHWA international scanning team that illustrates the relationship of performance management, risk management, and asset management to an agency's strategic objectives.

robustness. The capacity to cope with stress or uncertainty.

Sarbanes-Oxley. A 2002 U.S. statute that increased financial reporting requirements for publicly traded corporations. Its implementation led to increased risk management requirements for publicly traded corporations and financial institutions.

strategic risks. In this guide, strategic risks are described as ones that could affect an agency's major organizational objectives.

take advantage of. A risk response strategy in which the organization capitalizes upon a risk by seizing an opportunity.

terminate. This is a risk response strategy in which the organization avoids the risk by stopping a practice, or eliminating the source of the risk.

tolerate. This is to accept the risk and to take no additional steps beyond the controls inherent in the current business process.

transfer. This is the shifting of risk to another party. It generally occurs through a contractual arrangement, or payment.

treat. This is to mitigate the threat or variability by taking an action.

variability. In this guide, this term is used to mean a degree of change in a variable more than expected. It is not used in the strict sense used in statistics.

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