INCORPORATING RISK MANAGEMENT INTO TRANSPORTATION ASSET MANAGEMENT PLANS

Final Document

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PURPOSE AND OVERVIEW

The Moving Ahead for Progress in the 21st Century Act (MAP-21) amended 23 U.S.C. 119 to require State Departments of Transportation (DOTs) to develop risk-based Transportation Asset Management Plans (TAMPs). On October 24, 2016, the Federal Highway Administration (FHWA) adopted a final TAMP rule that elaborates on the MAP-21 requirements.

Both the statute and the FHWA rule identify the TAMP as a central part of the larger Federal performance management process. The TAMP is one of a series of plans State DOTs are required to develop to achieve the Nation's transportation goals. State DOTs will also develop plans for highway safety, congestion, and freight. These plans will influence and inform the larger transportation planning process and its products, the Long-Range Statewide Transportation Plan (LRSTP), and the short-term State Transportation Improvement Program (STIP).

This document provides guidance on the risk element of the TAMP, defines risk, and provides guidance on how the risk element can be applied to meet risk-based TAMP requirements.

First, this guidance provides background on the relevance of risk to asset management. Increasingly over the past decades, many sectors of the economy and of society have increased their focus on risk. This focus follows the increased emphasis on performance. A performance approach is defined as basing decisions on the pursuit of goals, objectives, and targets. More specifically, FHWA defines transportation performance management as a "strategic approach that uses system information to make investment and policy decisions to achieve national performance goals." This FHWA focus mirrors that of the private sector. Corporations are held accountable to achieve profit performance targets. Airlines must hit safety and on-time performance targets. Auto manufacturers must hit fuel-economy standards, while railroads must hit on-time delivery targets. As corporations, agencies, and institutions have adopted a greater emphasis on performance, they have recognized the need to manage risk. Only by managing risks can they achieve their goals, objectives, and targets.

The risk-performance relationship becomes more acute as performance objectives become more ambitious and long term. For example, it is much more certain that an agency can sustain its current pavement conditions for 1 year than for 10 years. As the time horizon for targets expand, the uncertainties increase.

Also, based on the current transportation funding environment, many agencies will lack the resources to achieve their targets. They must make trade-offs, lower some targets, and perhaps drop some important objectives. Trade-off decisions can become clearer when objectives and targets are viewed through the lens of which options reduce the top-priority risks, such as reduced risk to safety, asset performance, or future costs.

The required risk-based TAMP takes such risk-performance factors into account. Under MAP-21, State DOTs must develop 10-year asset management plans with investment strategies seeking to achieve and sustain a desired state of good repair (SOGR) over the life cycle of the assets. The most obvious way to assess the continued SOGR is to adopt short- and long-term targets reflecting the SOGR, and to measure actual performance against those targets. Setting targets and objectives 10 years into the future brings many risks. Risk-based TAMPs

acknowledge, identify, assess, and prioritize risks that could affect performance. They also help agencies make difficult trade-offs of scarce resources to address top-priority risks. By identifying risks, agencies can be more informed about managing their performance.

The intent of this guidance is to assist State DOTs with the development of their TAMP. However, the concepts can be applied to any transportation agency responsible for managing pavements, bridges, or other infrastructure assets. State DOTs are encouraged to engage partner agencies (including Metropolitan Planning Organizations (MPOs), local agencies, and Toll Authorities, for example) in the risk management process and encourage their use of risk management practices for managing their networks.

KEY CONCEPTS

The asset management rule, effective October 2, 2017, says State DOTs must establish a process for developing a risk-based, asset management plan, and it enumerates the information the process must produce.[1] The rule defines risk as "the positive or negative effects of uncertainty or variability upon agency objectives."[2] With this definition, the rule mirrors international standards that treat risks not only as threats but also as any uncertainties or variability that could impede an organization from achieving its objectives. While it may seem counterintuitive, managing risks also involves managing opportunities. A risk may be worth taking if its potential rewards exceed its potential drawbacks. In much of the corporate world, risk management is also used to identify which uncertain, but promising, opportunities to pursue—not just which threats to avoid.

The rule defines risk management as "the processes and framework for managing potential risks, including identifying, analyzing, evaluating, and addressing the risks to assets and system performance."[3] Risks can occur at multiple levels in an agency, including at the enterprise, program, project, or activity levels and affect an agency's asset management performance. An enterprise-wide risk could be a reduction in tax revenues. An activity risk could be a break down in data collection. Either could impede objectives, although they are managed at different levels.

A risk-based TAMP is one that identifies, assesses, and prioritizes the uncertainties, variability, and threats that could impede its objectives. A risk-based plan also may make trade-offs based on risks. Limited resources may be prioritized to high-risk assets or to make the transportation network more resilient to the greatest threats. A risk-based TAMP may also include the explicit taking of some risks to achieve even greater rewards. For example, an agency could experiment with chip seals and thin overlays on intermediate-volume routes to be able to afford more long-term pavement reconstruction projects on higher-volume routes. The agency may decide the risk of chip seals performing poorly may be worth taking if it allows more certainty that high-volume freight and passenger routes will achieve their performance and condition targets. Or, an agency may experiment with new, but promising, treatments knowing they are not risk free, but could

[1] 23 CFR 515.7.
[2] 23 CFR Part 515.5.
[3] 23 CFR Part 515.5. Note the asset management rule definition of risk management and the risk management steps it requires differ only slightly from those in the *AASHTO Enterprise Risk Management Guide*. The rule uses slightly different language such as "assessment" instead of "risk analysis." Users of the guide will find it helpful for developing the TAMP if they note these minor differences.

provide higher performance for lower costs. Or, an agency could allow a low-risk asset to deteriorate below its desired target to address a higher-risk structure or traffic-control device.

The objective of a risk-based TAMP is not to avoid all risks. Rather, it is to acknowledge risks, assess and prioritize them, and allocate resources and actions based on the agency's risk tolerance and how the risks could affect the asset management objectives.

The focus on uncertainty and variability highlights the importance of managing both opportunities and threats to the agency's priorities. Risk management heightens the identification of threats that could impede objectives, particularly threats to the public's safety and well-being. A risk-based TAMP should identify high-risk assets, such as structures prone to seismic or scour damage. Frequent flooding and increasing storm frequency and severity could be a significant risk to agencies hoping to sustain asset-condition targets for the next decade. Even economic factors can be threats. The loss of competition can drive up material and construction prices, which can threaten an agency's ability to afford all the projects it needs to achieve condition targets. Economic downturns that reduce tax receipts or prompt legislators to reallocate appropriations could be threats identified in a TAMP.

A risk-based TAMP will identify, assess, evaluate and prioritize the asset management risks and summarize how the agency plans to mitigate or take advantage of them. Additionally, a risk-based TAMP will acknowledge the uncertainties an agency has to address. These could be uncertainties about future revenues, long-term material performance, unit costs, changing agency priorities, or other relevant matters. Finally, a risk-based TAMP will identify the external threats that could impede performance, be they from the climate, geology, the economy, or the political environment.

GETTING ORGANIZED

This section summarizes steps to organize and conduct risk analyses. More detailed information is available in the American Association of State Highway and Transportation Officials (AASHTO) *Guide for Enterprise Risk Management*. A summarized *Quick Guide* is available from AASHTO at no charge[4]. Although the full *AASHTO Guide for Enterprise Risk Management* and its *Quick Guide* are helpful for enterprise risk management, they are not written specifically to address the MAP-21 risk-based, asset management requirements.

Forming a Risk Team

Because risks can come in many forms, it is important to have a diverse and representative team to identify and prioritize them. A risk team should be formed with the key stakeholders who will develop a TAMP. Table 1 provides an example.

The role of policy makers is particularly important because they determine how the agency aligns risk management with agency processes. Preferably, the risk management exercise is not an isolated activity only for the TAMP. To be most effective, the agency should actively manage the risks as part of its performance-management program. As risks are identified, "owners"

[4] *AASHTO Guide for Enterprise Risk Management: Quick Guide*

should be identified and, when possible, tasked with identifying, analyzing, evaluating, and addressing the risks. This assignment of risk responsibility parallels the assignment of performance responsibilities. As executives assign staff the responsibility to address specific performance areas, they also assign the same staff the responsibility to manage the risks to those performance areas.

Local agencies can be important participants, particularly when they own substantial National Highway System (NHS) assets. Their early involvement can bring them into the process and help them and the State DOT better understand risks surrounding condition and performance of the locally-owned assets.

Table 1. Risk team members and their roles.

Discipline	Role or Contribution
Finance Staff	Forecasting expected revenues available for asset investment.
Asset Modelers or Forecasters	Providing scenarios of how much investment is needed to achieve and sustain asset-condition targets. Producing scenarios of alternative treatment strategies to manage risks to a fiscally balanced program.
Planners	Forecasting traffic, and population trends affecting asset investment levels.
Pavement, Bridge, other Asset Engineers and Asset Owners	Providing insights on condition trends, asset performance, emerging issues and assessing, prioritizing, and developing mitigation strategies for high-priority risks.
Programmers/Estimators	Estimate unit costs and pricing trends that will influence investment assumptions.
IT Staff	Provide support for data extraction, analysis, mapping and managing the technical aspects of developing and maintaining the risk register for enterprise use.
Maintenance Staff	Offer insights on maintenance trends, costs related to achieving condition targets.
Environmental Staff	Identifying, assessing, evaluating, prioritizing, and developing mitigation strategies for high-priority, current, and future environmental risks.
District or Field Staff	Provide insights on how risk and performance issue vary across the State.
Safety Engineer	Comment on the role, if any, of asset conditions on safety trends and priorities.
Local Owners of NHS Assets	Identify and address risks to locally owned assets addressed in the TAMP.
Policy Makers	To evaluate key policy trade-offs, such as lowering asset targets or prioritizing investment. Also, articulate how the TAMP and its risks will be incorporated into agency decision making, policies, and procedures.
TAMP Risk Manager	This is a role of the group or person(s) responsible for coordinating the updates to the TAMP to reflect changing risk priorities. Without this role, any new risks may not be reflected in the TAMP. This can be a person from any of the other groups or a person specifically assigned to coordinate updates to the TAMP. By assigning this role at the start of the TAMP development, the agency is assured the TAMP reflects new high-priority risks that arise, such as budget cuts, new taxes, or safety incidents.

GETTING STARTED

The risk management workshops operate best with a strong facilitator who organizes meetings, sets a schedule, and clearly articulates the group's objective. The objective is to identify, analyze, prioritize, and describe how to manage risks to the agency's asset management objectives. It is preferable if the facilitator has no vested interest in the outcome of the exercise and can engage the entire group to think through the risk management process for all areas relating to the TAMP during the exercise.

The type of data and information the group should compile for its workshops will include, but is not limited to:

- Past trendlines of asset conditions and the accompanying expenditures.
  - Have conditions trended positively or negatively, and how were those trends affected by programming decisions?
- Asset management goals and targets.
  - How were the goals and targets developed?
  - Have they been achieved in past years?
  - Do goals and targets take into consideration the long-term, desired SOGR?
  - Do staff believe they are reasonable, too high, or too low?
  - Does the agency have targets for all assets it will include in the plan?
- Financial forecast and its assumptions.
  - Are revenues rising, falling, or are past sources expiring, such as bond receipts?
  - Are there new initiatives of expansion, safety or other agency high priorities that require funding and have they been considered in the future projections?
  - How much will be available for investing in assets?
  - How certain is the forecast?
- Information about major influences that will affect the TAMP.
  - Does the agency expect changes in population, traffic, contractor availability, climate, sea levels, or even revenues and appropriations, that could affect the TAMP?
  - Does the agency have many structurally-deficient structures, aging assets, or deteriorated assets that will influence the financial plan?
- Key assumptions around forecasts of bridge, pavement, and other asset investment needs.
  - What were the assumptions related to: inflation rates, asset deterioration rates, material performance?
  - What is the accuracy or confidence in the models that produced the forecasts?
- Studies or forecasts for environmental risks that could affect asset performance or agency costs.

- What are the likelihood and anticipated severity of seismic activity or extreme weather events?
- In addition to the Part 667 requirements, does the agency have assets from past events that need to be addressed (e.g., excessive floods that have created ponding and expedited asset deterioration or fires that have destabilized slopes)?

Supporting Tools

A State DOT can use a variety of tools to develop its analysis. The *AASHTO Guide for Enterprise Risk Management* provides examples of different workshop techniques and several tools that can assist the analysis process.[5] One key tool is the risk matrix shown in figure 1. These are nearly universal in risk management. They provide staff a common scale by which different groups can assess the likelihood and impact of different risks. With likelihood and impact estimated, the group can assign a value to a risk's consequence. As seen in the matrix, a risk's consequence is the product of its likelihood times its impact. For example, a volcanic eruption's impact could be catastrophic, but its likelihood is so rare that it does not generate a high risk value. However, an inaccurate pavement model may not be catastrophic in terms of lost lives, but its chronic and ongoing inaccuracy creates a significant risk to the accuracy of investment forecasts. The risk matrix summarizes the essential nature of risk, which is a function of both its likelihood and its impact.

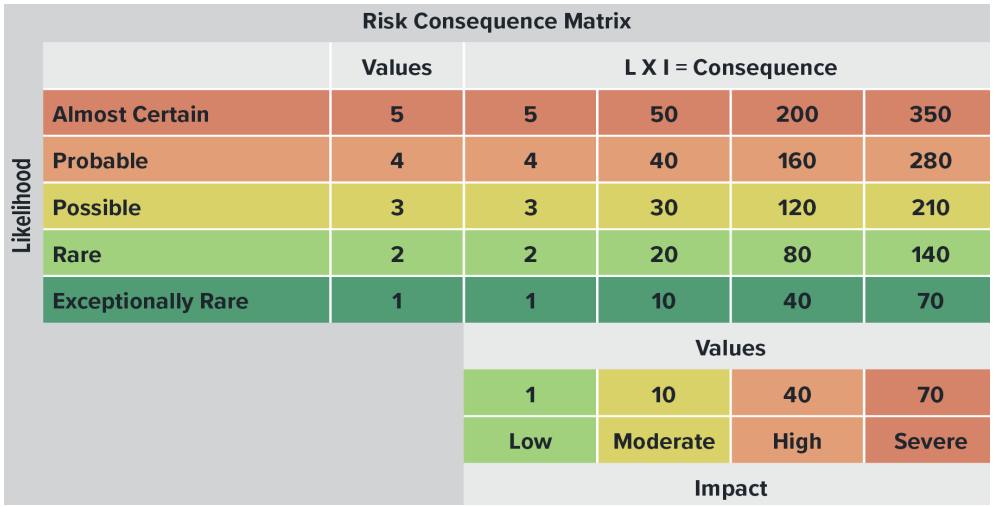

Figure 1. A likelihood and consequence matrix.

Definitions of each category of likelihood and impact are also helpful. Examples are provided in the *AASHTO Guide for Enterprise Risk Management*.[6] The definitions keep participants "on the same page" as they discuss the consequences of dissimilar risks. After workshop members identify risks, plot them by their likelihood and their impact to generate a value. These values allow comparison and ranking of dissimilar risks.

[5] Pages 34–41, pages 53–59
[6] Pages 68–72

The workshop requires few additional tools. However, it helps if participants are prepared to discuss the high-priority objectives and impediments to achieving those objectives in preparation for the session. The workshops should be timed to occur along the TAMP-development schedule and contribute to the plan's development.

Explaining the Risk Management Process

Although applying risk management to assets is relatively new to U.S. transportation agencies, risk management is a well-developed practice in private industry. Guides and templates exist that agencies can follow. The *AASHTO Guide for Enterprise Risk Management* is based on the ISO 31000 standard. The International Organization of Standardization (ISO) is a Swiss-based, voluntary organization that develops international business standards. Figure 2 is modified from ISO and the *AASHTO Guide for Enterprise Risk Management* to include the information that the FHWA's asset management rule says States' risk management plans should include. The figure encapsulates the steps to follow and the information to produce the risk portions of a TAMP. The steps shown are universal and can be applied to manage risk to a single topic, or they can be the ongoing steps agencies take to manage all risks on an annual cycle.

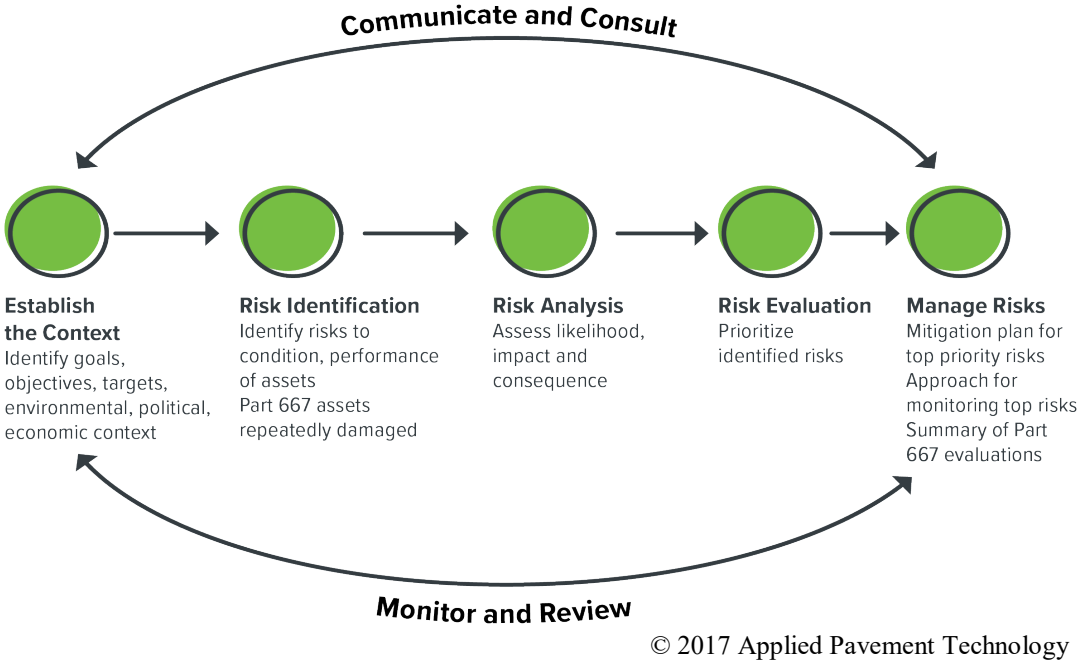

Figure 2. The risk management process.[7,8]

Step 1 begins with "establishing the context." In this step, participants identify the agency's asset management goals, objectives, and targets. Recall that risk management supports and parallels performance management. Therefore, risk management should be "goal oriented." The participants focus on the risks to the TAMP's objectives and targets.

[7] *Risk Management – Principles and Guidelines*, ISO Standard 31000, First Edition, 2009-11-15, International Organization for Standards, Geneva, Switzerland.
[8] *The AASHTO Guide for Enterprise Risk Management,* First Edition, AASHTO 2016 available as an electronic document from the AASHTO Bookstore.

Also in step 1, the participants identify the most relevant issues in the agency's asset management environment. What trends are occurring? Is revenue rising or falling? Is there agency and political support for asset management? Does the agency have clear objectives and targets? Are there other short and long-term goals and objectives that influence the agency's TAMP? For example, in 2017, some of the southern State DOTs were still addressing the impacts of Hurricane Matthew and this could influence their TAMPs. Some States are raising revenue through other State sources. In short, what is the context or environment in which the agency pursues its asset management objectives, and how could it influence the plan?

Step 2 is risk identification. In workshops, participants identify as many risks as possible. To elicit risks, facilitators can rely on brainstorming, round-robin, preestablished checklists, scenario review, and other tactics. The intent is to have the broad cross section of participants on the risk team identify risks to the asset management objectives. Because risks can be internal or external, the diverse representation on the risk team is helpful in identifying a wide array of risks.

Participants should identify both short and long-term risks, even if they may not occur during the 10 years covered in the TAMP. Although the plan's horizon is 10 years, the life cycle of assets could be 50 years or more. The agency should identify all risks to assets, even those beyond the 10 years of the plan, such as long-term climate conditions or seismic risks.

Recall that risk management addresses threats, opportunities, uncertainty, and variability surrounding asset management objectives. In this stage, participants should not only identify threats, but also potential opportunities. There may also be uncertainties in forecasts or variability in performance that merit analysis.

The agency will find it helpful in later steps if risks are written in the format of an "if-then" risk statement. Risk statements have a simple sentence structure of subject, verb, and object. The subject is the nature of the risk, such as "funding shortfalls." The verb is the impact such as "will reduce our investment in assets" and the sentence's object is "and prevent us from achieving our asset-condition targets." The agency's resulting risk statement is: "If funding shortfalls occur, then we will reduce our investment in assets preventing us from achieving our asset-condition targets." It is tempting for workshop participants to just identify "funding" or "politics" as risks, but this makes it difficult in later steps to identify how to prioritize or manage such a broad topic without the detail provided by a full risk statement.

The product of the second step should be a list of risk statements with subjects, verbs, and objects, such as: "If our pavement model is unreliable, then it reduces our confidence in our forecasts and leaves us doubtful if we will achieve our pavement condition targets." This statement describes a risk topic, its immediate impact, and its long-term results.

Another set of risks to be identified are the facilities damaged during emergency events that are referenced in 23CFR Part 667. Part 667 carries out language Congress included in the Fixing America's Surface Transportation Act, or FAST Act.[9] The regulation requires analysis of alternatives to roads, highways, and bridges that have required repair and reconstruction on two or more occasions due to emergency events. These assets are to be identified and considered later in the risk monitoring efforts, and when programming projects.

[9] Pub. L. No. 114-94 (December 4, 2015).

Step 3 is to analyze or assess the risks. Team members analyze the likelihood and impact of each risk statement. Then, using the likelihood and impact matrix, they assign a consequence value to each risk, which is the product of its likelihood times its impact. These values are judgments based on the opinions and experience of the participants. Risk experts emphasize not to "overthink it." This exercise captures the collective experience and judgment of the staff, which is extremely valuable. If a broad cross section of staff is involved, the risk analysis will represent the collective opinion of staff as to the relative impact and probability of each risk. The product of this exercise is a ranking of the risk statements.

Step 4 is to evaluate and priortize the risks. Although this sounds similar to step 3, it is subtly, but importantly, different. In this step, participants prioritize risks for treatment based on the consequences of the risks to the asset management objectives. The risks are compared to the agency's risk appetite. The risk appetite is the threshold or tolerance for risk, which can be quantitative or qualitative. In the corporate world of insurance or finance, the risk appetite is a finite number or threshold. In other sectors, the risk appetitite is a qualitative threshold, such as a low tolerance for risk to ethics, public safety, or the enivronment. Prioritization provides a relative ranking of the risks and enables an agency to understand the relative importance of managing risks. Therefore, either qualitative or quantititave tolerances will serve the purpose of prioritization.

In this step, the agency reviews its risk tolerance. If it has not been defined by the agency, participants will define the risk tolerance. Participants will compare each risk to the agency's risk tolerance and address questions such as: "Is this risk beyond the agency's risk tolerance?" Risks determined to be beyond the agency's risk tolerance need to be addressed.

Step 5 identifies how to mitigate and who manages the risks. The final asset management rule in 23 CFR Part 515.7 calls for agencies to develop a mitigation plan for their top-priority risks and to identify an approach for monitoring them. In addition, 23 CFR Part 515.7(c)(6) says agencies must provide a summary of their evaluation of facilities repeatedly damaged by emergency events, that at a minimum, discusses Part 667 results relating to the State's NHS pavements and bridges. Addressing the risks to critical infrastructure mentioned in 23 U.S.C. 119(j) is optional. This provision was added in the FAST Act and defines critical infrastructure as facilities where "the incapacity or failure of which would have a debilitating impact on national or regional economic security, national or regional energy security, national or regional public health or safety, or any combination of those matters."[10] Section 119 allows Federal funds to be used to reduce the risk of critical infrastructure failure.

This step builds on step 4, where the participants prioritized the risks based on the agency's risk tolerance. Participants determine if the agency can treat or capitalize on a risk. To treat would be to address or ameliorate the risk, while to capitalize would be to take advantage of the risk, such as a promising new product or treatment. Not all risks can be treated, as many are beyond the agency's influence. For instance, agencies will be unable to prevent some risks, such as economic downturns reducing tax receipts. Treatment for such risks may involve developing contingency plans in case they occur. However, there are other risks that the agency can treat. The agency could decide that it can treat an internally-generated risk, such as inadequate data or an uncertain model. In this step, participants address questions such as: "Is this risk treatable?"; "Is it within our jurisdiction?"; or

[10] Fixing America's Surface Transportation Act, page 129.

"Is it 'owned' by another agency?" External risks, such as economic downturns or natural disasters, that are beyond agency control, may not be treated; but the agency will monitor them or perhaps develop contingency plans to implement if they occur.

In this step, the participants identify the approach to mitigating the risk. They could treat it by taking an action or tolerate it because they can't eliminate it and instead accept it and monitor it. They could terminate it by ending the practice that causes the risk. They could transfer it by passing the risk on to contractors or design consultants. Or, they could take advantage of it by capitalizing on the risk. If timely project delivery is a risk, design-build could be an option. Design-build does not eliminate project-delivery risks; however, it can expedite project development if the agency is willing to transfer the project delivery risk and accept other risks, such as less control over design and construction. In the "take advantage of" option, participants may decide a risk is worth taking even if it produces other risks.

Steps 6 and 7 are to monitor the risk, communicate and consult about the risks, and to carry out the risk plan. In a robust risk management process, these are not isolated steps but ongoing, continuous processes. Communicating and consulting involves publishing the risks, and how the agency plans to manage them. Then, key internal and external groups are consulted so they are aware of how the risks could affect performance. For instance, the agency could include local stakeholders and its MPO or legislators as it develops the risk management plan for the assets addressed by the TAMP. Events or actions could increase or decrease the likelihood or consequence of a risk, changing the agency's risk profile. Also, included in the risk plan is the summary of the evaluation of facilities that were repeatedly damaged by emergency events.

At a minimum, the communicating and monitoring steps involve including the agency's risk management plan in the TAMP.[11] A useful element of the plan can be the risk register. The risk register can be expressed as a simple table consisting of the risks, how the agency plans to manage them, and who is responsible, as seen in table 2. It can be incorporated into the TAMP and periodically updated by the risk team.

Risk management is a dynanic process, and the contents of the risk registers and risk treaments can change as risks change over time.The risk register is a dashboard of the agency's risks. Therefore, it is important to keep the risk register updated to reflect the changes in the high-risk priorities. A risk register that is outdated does not provide any value to the risk mitigation process or to decision making. To fully incorporate risk management into the agency, the risk registers should be reviewed and updated along with the performance-review processes. As the agency reviews performance periodically, it also can review how it is managing the risks to that performance. Additionally, the risks to performance can be referenced in LRSTPs, agency budget testimony, and in other strategic, planning, or performance functions.

Table 2. A simplified risk register.

Risk	Likelihood	Consequence	Treatment	Owner
Pavement Model Uncertainty	Almost certain	High	Improve model data, deterioration curves	Pavement Management Unit

[11] 23 CFR 515.7(c) and 515.9(d)(6).

IDENTIFYING AND MANAGING HIGH-PRIORITY, ASSET MANAGEMENT RISKS

Each agency faces unique risks related to its climate, geography, geology, financial structure, management systems, and political structures. A single list cannot capture all the risks that could affect the asset management objectives of all 50 States, Washington, D.C, and Puerto Rico. However, there are some common areas that are likely to appear in most risk registers.

Risks Associated with Current and Future Environmental Conditions

Extreme weather events, climate conditions or seismic activity are likely to be among the current and future risks identified by many agencies. As these risks become more severe, they are likely to affect agencies at least once during the 10 years of the TAMP. Additionally, managers should also consider longer-term risks that can be most cost-effectively addressed during the 10-year period of investments, even if the risks are expected to be realized only after this specific TAMP period. The impacts could be as minor as occasionally washing out culverts or causing roads to be closed. Or, they could be serious enough to require abandonment of some routes and higher costs to expand drainage structures to keep assets serviceable.

Addressing risks can include:

1. Steps to prepare for immediate risks, such as storm damage or flooding related to higher tides during the 10 years of the plan.
2. Longer-term risks that may not occur during the life of the plan, but which could be mitigated during the TAMP's 10-year period, such as planting grass below the water line to reduce wave impacts, or recalculating the required size of drainage structures as they are replaced.

The sophistication of how agencies analyze risks can vary. At a minimum, the TAMP could note whether its risk management plan is based on current climatic conditions, and if those vary, the agency's objectives may be affected. The effect could be higher costs to repair assets or delays in improving other assets as the agency responds to storm events. At a more sophisticated level, the agency's TAMP may use the results of a thorough risk analysis as supported by the FHWA's *Climate Change & Extreme Weather Vulnerability Assessment Framework*.[12] The FHWA supported 24 State DOTs and MPOs that applied the assessment framework to identify risks to their systems and specific assets. Other examples of in-depth risk analyses include the *Gulf Coast 2* study and the *Hurricane Sandy Follow-up Study*.[13] The State DOTs and MPOs that participated produced detailed analyses of the increased likelihood of extreme weather events based on climatic modeling. Using the results of that modeling, agency team members assessed how the events could impact roadways, bridges, drainage structures, transit facilities, ports, slopes, and critical facilities such as transit stations. These more detailed analyses can provide the risk register with a robust set of risks and impacts that could be included in the TAMP.

[12] FHWA, Resilience, at https://www.fhwa.dot.gov/environment/sustainability/resilience/.
[13] See FHWA's Resilience website for these and related publications.

Higher sea levels and tidal impacts may be a significant risk in coastal areas, and would be appropriate to include in the asset management risk register. Super Storm Sandy's inundation of subway tunnels represents just one example of the risks posed by higher sea levels, tides, and storm surges. Agencies managing coastal assets may need to identify and manage these types of risk, which could increase their future costs and reduce future condition and performance.

Extreme drought creates multiple risks that could be acknowledged. The Mississippi DOT reported how the extreme southeastern drought shrank clay soils resulting in early pavement failures, increased costs, and reduced pavement conditions.[14] Colorado DOT officials note that increased drought contributes to wildfires which denude slopes and exacerbate flooding. They reported that the Waldo Canyon fire near Colorado Springs in June 2012 was followed by 13 road closures in 2013 caused by flooding, mud flows, and debris on the adjacent U.S. Route 24.[15] Another Colorado official reported that fire damage creates flooding impacts for up to a decade until plant regrowth stabilizes slopes.[16]

Geologic risks can affect TAMPs even if no seismic event occurs. For example, if agencies are mitigating seismic risks by retrofitting structures, it consumes resources that otherwise could be spent on achieving asset-condition targets. In such circumstances, the agency may decide to accept lower condition targets to invest more resources in seismic retrofit projects. Conversely, the agency could report that achievement of safety, economic vitality of the region, continuity in freight movement and its asset-condition targets will be dependent on having no major seismic events. If a major event occurs, "all bets may be off" that it can methodically plan and deliver projects to achieve its condition targets during the 10 years of the plan.

For both climatic and geologic risks, the agencies may want to summarize how these risks affect resources, could affect performance, and influence trade-offs, both now and in the future. Agencies may be spending significant sums to seismically retrofit major structures that will be vital for evacuation or emergency relief after a major event. Or the agency may be investing to expand drainage structures or elevate assets to reduce flooding impacts. These investments may reduce funds available for achieving asset-condition targets. However, they may reduce the probability of even greater impacts to system performance and asset conditions.

The information from the 23 CFR Part 667 evaluations can contribute to the discussion of climatic or seismic risks. Part 667 requires agencies to identify facilities that have required repair and reconstruction two or more times since Jan. 1, 1997, during formally declared emergency events. The Asset Management Rule requires inclusion in the risk management analysis of the results of the Part 667 evaluations for NHS pavements and bridges.[17] Agencies can consider how this evaluation of the damaged facilities can best inform the preparation of its asset management plan and STIP.

[14] Mississippi Department of Transportation, news release, Nov. 29, 2016.
[15] Colorado DOT, Frequently Asked Questions accessed Dec. 14, 2016, at https://www.codot.gov/projects/us24utepass/us24faqs.html.
[16] Yochum, S., Wildfire-Induced Flooding and Erosion – Potential Modeling: Examples from Colorado 2012 and 2013, U.S. Forest Service April 2015.
[17] 23 CFR 515.9(d)(6).

High-Risk, High-Value Assets

The agency may also want to identify high-risk, high-value assets. These assets could be critical high-cost, high-traffic facilities, or even low-volume facilities, if they are the only facility serving a large area. If high-volume structures and roadways are subject to hydrologic, seismic, or geologic threats, they are likely to be identified when climatic and geologic risks are identified. However, other assets could be identified as high risk because of advanced age, deterioration, or other vulnerabilities. These may be singled out for attention in the risk register. Examples include high-volume (but Poor condition) structures, roads that are communities' only evacuation routes, slopes prone to failure, or assets subject to regulatory compliance (such as drainage structures in ecologically sensitive areas). Any of these could be identified as high-risk assets requiring increased investment, treatment, or monitoring.

The agency's TAMP could address these high-risk, high-value assets in several ways. It could allocate additional resources to them by reducing investments in lower-risk assets. Or, the TAMP could note that it only plans to monitor the assets' conditions during the 10 years of the plan, but if they deteriorate further, they may warrant reallocation of TAMP investments. Or, it could develop advanced monitoring and maintenance plans to reduce risks to the TAMP investments.

Similarly, the TAMP could set higher condition targets and allocate greater investments for high-value assets. These could be as traditional as the higher-functional class routes, such as the Interstate Highway System and NHS segments. Deterioration and decreased performance of these routes increases the possibility that the agency will not meet the public's performance expectations. Degradation of these routes is considered a performance risk and could result in expensive future action that the agency seeks to prevent.

Financial Risks

An agency's financial plan with forecasts of revenues and expenditures for 10 future years will inherently have uncertainties. Documenting the uncertainty surrounding financial assumptions increases the credibility of an asset management financial plan.

Revenue forecasts are based on assumptions of fuel consumption, motor fuel tax rates, fee levels, and State and Federal appropriations, among others. Some States, such as Alaska and Texas, are influenced by energy prices because of their State government's tax energy production. Agencies reliant on sales taxes are influenced by economic downturns, particularly of big ticket items such as automobiles. Revenue forecasts can become inaccurate if assumptions around any of these factors change during the life of the plan.

Developing revenue forecasts based on the consensus opinion of a panel of experts is a good practice. The panel could review past revenue trends, evaluate emerging issues, and reach a consensus forecast of the rate of change of any of these sources. Related to this, the agency could produce low, medium, or high forecasts to illustrate the significant effects that assumptions can have on revenue forecasts. To go even further, the agency could conduct a Monte Carlo simulation of its revenue forecast, as described in the *AASHTO Guide to Enterprise Risk Management*.[18] These methods acknowledge the uncertainty surrounding the revenue forecast. A

[18] Pages 198 to 207.

very conservative forecast can justify low-condition targets and the agency's reluctant acceptance of declining conditions. A robust forecast could justify higher targets and ambitious investment strategies. Both the conservative and robust forecasts contain risks. A forecast that is too low could lead to diminished investments and declining conditions. An overly optimistic forecast can lead to misplaced confidence that the agency will have the funding needed to achieve its targets. Documenting the assumptions, uncertainties, variability, and threats to the financial forecast strengthen a risk-based TAMP.

Another risk faced by several agencies in recent years is reappropriation of transportation funds to other agencies or uses. In times of tight State finances, some legislatures have taken transportation funds and reallocated them to balance State budgets. Any probability of this occurring represents a risk that could substantially reduce the planned investment levels.

Bond income represents another potential risk. During the tight budget years of the mid-2000s, many agencies increased their bonding. Now, they face not only an end of the bond income, but also higher interest and principal payments. Forecasting may be an important component of the agency's financial risk profile if debt represents a threat or an opportunity. An agency with low debt levels may have an opportunity to balance a financial plan with prudent borrowing.

An inflation forecast is also important. In the 3 years preceding the recession that began in December 2007, construction costs rose steadily and eroded purchasing power. Since then, inflation has moderated. However, any 10-year capital investment forecast such as a TAMP is sensitive to construction and material cost fluctuations. Above-expected inflation could be caused by global issues such as international oil prices, Mideast conflict, or an overheated international economy. At a regional level, construction-cost fluctuations can be influenced by a lack of contractor competition, or regional aggregate shortages. Such issues significantly affect a district or region's construction costs.

Financial risks present a good example of risks that merit ongoing monitoring and review, communication, and consultation. Periodically, the agency can assess tax receipts, appropriations, and construction prices to determine if it needs to update its revenue forecasts. If so, these updates can be communicated to key stakeholders.

Legal or Compliance Risk

Changes in legal requirements can present significant uncertainty or variability that can affect the asset management financial plan. Compliance with curb ramps or water-quality standards can have a significant effect on asset budgets. These requirements represent social and environmental objectives. However, they usually occur in a zero-sum financial environment. The inclusion of curb ramp construction or retrofit in an agency's pavement budget adds a significant new cost which reduces the amount of pavement investment. Similarly, the structure's budget is affected if it must accommodate new costs for catch basins and best management practices. These are the types of emerging issues that can be identified in the first step of the risk process, identifying the context and environment.

Demand Risks

Changing regulation, population, or land uses can create new uncertainties that may not have affected the agency in the past. These can be grouped under the category of demand risks. The demands on the agency's assets may change or be uncertain.

An example can be heavier truck weights or reduced axle spacing permitted by the legislature, which increase demands on an agency's assets. Greater weights can increase pavement and bridge deterioration and lead to higher costs over time. Documenting these uncertainties in the TAMP can explain why current investment levels may not guarantee achievement of future asset-condition targets.

Other examples affecting agencies are heavier truck volumes caused by energy extraction, mining, timbering, or even grain shipments. Operations such as fracking increase localized truck volumes and weights that can reduce asset conditions, particularly on lightly constructed low-volume routes. These trends may be worth citing in the TAMP, even if they only affect regional asset conditions and costs.

Similar risks that could be categorized in either the legal/compliance area or the demand area are legislative mandates for agencies to take on new responsibilities. They can include shifting responsibility from locals to the State for maintenance of some assets, such as State routes within cities. Taking on this responsibility represents a substantial new obligation that puts the agency's ability to achieve its condition targets at risk.

Population growth and greater travel demand also can be an uncertainty worthy of mention in the TAMP risk register. This can be particularly true in high-growth States and regions. Even if travel demand is not sufficient to degrade pavements or bridges, if it creates demand for new capacity projects, it can represent an uncertainty whether enough resources will be provided to sustain existing asset conditions.

Information and Decision Risks

The quality of the TAMP rests on the quality of the data, forecasts, projections, and assumptions within it. It may behoove an agency to acknowledge the risks surrounding its data, forecasts, projections, and assumptions.

Many agencies will be developing TAMPs based on new models and incomplete data. "Beginning with what you have" is standard asset management advice. Agencies are urged to start managing their assets and improving their processes over time.

"Beginning with what you have" inherently requires an agency to make assumptions with less than comprehensive analysis. Making initial decisions and forecasts on partial information is unavoidable, but its risks can be addressed by simply acknowledging them. The agency may want to couch its pavement or bridge forecasts with acknowledgment of the uncertainties that surround them. Such hedging of forecasts is common in the corporate world where "model risk" or "decision risks" are accepted as being unavoidable. In their annual reports to shareholders, corporations often state the assumptions in key models and advise investors that these assumptions represent risks. The risks are reduced by monitoring developments to determine if they unfold as predicted. Also, the models are periodically updated with fresh assumptions as

more data become available. Model risk cannot be eliminated, but it can be reduced by frequent updates and amendments to forecasts based on new data. Since some model risk is unavoidable, agencies should acknowledge it, and explain how the model's forecasts may change over time.

Model risks and decision risk often are actionable. They represent risks that agencies can actively reduce over time. Decision-risk-reduction strategies can include increased targeted data collection, model validation, training of modelers, and recalibration of models as forecasts and actual results are compared over time.

Operational Risks

Operational risks are widely recognized in the corporate world and are equally relevant to public-sector transportation agencies. Operational risks include a broad category such as internal procedural breakdowns, staff turnover, loss of staff expertise, agency down-sizing, and other internally generated acts or omissions that could impede asset management performance.

Staff turnover or downsizing of data-collection staff could reduce the quality and timeliness of data that support asset management decision making. Also, a loss to retirement or attrition of key staff such as analysts and modelers could potentially affect asset management functions. They often require extensive training to be adept at complex analysis and modeling. The loss of these staff can affect decision making or the agency's ability to produce multiple investment scenarios.

Other breakdowns could include a shift in internal priorities between divisions so that one unit no longer fulfills its asset management activities. For example, a reduction in maintenance funding could reduce the amount of bridge maintenance activities; or, reduced maintenance funding could impede the amount of drainage maintenance, crack sealing, or other key asset management support functions.

Project-development delays also can represent an operational risk. A well-rounded asset management program will include the appropriate "mix of fixes" of preservation, maintenance, rehabilitation, and replacement treatments. The complex rehabilitation and replacement projects may take years to develop. Project-development breakdowns can represent a risk to delivering these projects and achieving the asset-condition targets.

Hostile Acts, Malfeasance, Accidents

In the corporate world, risk managers often identify criminal acts, malfeasance, and threats as common as fires and accidents as risks against which they act. These also may be risks agencies can identify and prevent. Some examples include hacking into a traffic management system, malicious code in an asset management system, or oversize truck crashes into bridges. Although these may not rise to the level of an enterprise-wide risk, they may be risks at the asset or program level the agency may want to consider. For example, agencies have increasingly developed "hot sites" for backup data storage and IT functions in case their main centers are stricken by fires or floods. An agency could identify reducing risks to critical assets such as computer systems and traffic management centers as a risk-reduction strategy.

THE ROLE OF RISK MANAGEMENT: EXAMPLES FROM PRACTICE

The next section provides examples of how risks are addressed in U.S. and international TAMPs. The examples illustrate at least five ways to use risk management information in asset management plans and processes:

1. The first is to provide information. Some of these examples give a "heads up" to the TAMP stakeholders and policy makers that these risks could impede achievement of the asset management objectives. The risk management objectives are couched with the warning that these risks exist, they could arise, and could prevent the agency from carrying out the TAMP as expected.
2. The second is to reduce performance failures. The agency may identify internal performance risks or external influences that could reduce the probability that it will achieve its asset management objectives.
3. The third is to set staff priorities. An example could be increasing data-collection efforts, improving modeling, or building asset inventories to reduce the risk of Poor asset performance.
4. The fourth role is to prioritize capital investments. Agencies may identify high-value, high-risk assets or networks prioritized for increased investment or monitoring.
5. The fifth is to improve resilience. Several of the plans focus on assets to make them more robust to withstand increased storm events, seismic activity, or geologic events.

Utah DOT

The Utah DOT uses risks to prioritize investments.[19] Its TAMP places all assets in three tiers, with Tier 1 assets being those with the highest value and the highest negative risk of financial impact if they are poorly managed. They are singled out for accurate and sophisticated data collection, tracked with targets and measures, and supported with predictive modeling and risk analysis. Included in this tier are pavements, bridges, and advanced traffic management systems and signals. Tier 2 assets include culverts, signs, retaining walls, barriers, pavement markings, and curb ramps. They have more moderate risks and warrant less than annual data collection, risk analysis upon failure, and "spreadsheet" management strategies. Tier 3 assets are inventoried less than annually, risk is assessed upon failure, they receive only general condition analysis, and are repaired or replaced when damaged. These Tier 3 assets include fences, rest areas, cattle guards, and interstate lighting.

The agency also assigns risk values to the many activities included in accomplishing its asset management road map. Each task and its risk are evaluated and risk matrix values of probability and impact are used to prioritize risks. Some high-risk, asset management activities assigned to staff include improving bridge condition data and analysis, integrating business systems and databases, and refining performance measures to capture risks and life-cycle costs.

[19] Utah DOT Transportation Asset Management Plan, January 2016, pp 4.

Minnesota DOT

The Minnesota DOT (MnDOT) includes a risk chapter in its TAMP.[20] The MnDOT already had a robust risk management program that addressed many of the types of risks discussed in this guidance. Its bridge program routinely addresses risks such as deteriorated structures, scour, fracture criticality, fatigue cracking, overloads, and collisions with over-height vehicles. Risks to pavement performance are also incorporated into pavement investment decision making.

The MnDOT focused on "undermanaged" risks and its ongoing asset management process for special emphasis in its TAMP. The most critical included roadway sections in Poor condition for more than 5 years, deep storm water tunnels, culverts for which the agency lacked a thorough monitoring program, overhead signs, and high-mast light structures.

The MnDOT also conducted a flash flood vulnerability and adaptation pilot project assessment that addressed potential changes in flooding tied to storm events.[21] It plans to share the results of the analysis with other State and local agencies and establish a collaborative effort to better define and address these risks.

Colorado DOT

The Colorado DOT TAMP includes a risk register that identifies and prioritizes risks.[22] Agency-wide, high-priority risks include inadequate funding, lack of support for asset management, negative public perceptions of the agency, and political and leadership changes that could reduce asset management support. At the program level, risks include the need for an expensive new tunnel that will absorb funding from other projects, retirement of key staff, impacts from inadequate data management, and unreliable program delivery. Numerous project-level risks were cited, including burn areas and the slope failure and flooding they exacerbate, flooding in general, landslides, rockfalls, serious tunnel fires, and avalanches.

New York State DOT

The New York State DOT TAMP included an initial risk register.[23] It cites risks including inadequate Federal funding and restrictions on how those funds can be used that could result in deteriorating conditions and inability to meet condition targets. Also, non-NHS assets will continue to deteriorate because of the disproportionate use of Federal funds on the NHS. Another risk is more intense storms and sea level rise that will result in more flooded assets, higher repair costs, and additional costs to harden existing assets. Another risk is of inadequate resources to produce accurate, timely, and complete asset inventories. This risk could preclude achieving performance targets, developing accurate estimates, and reaching well-informed decisions.

[20] Minnesota DOT Transportation Asset Management Plan, 2013, pp 50 – 60.
[21] Minnesota Department of Transportation, MnDOT Flash Flood Vulnerability and Adaptation Assessment Pilot Project, Final Report, 2014.
[22] Colorado DOT Risk-Based Asset Management Plan, 2013, section 7.
[23] NYSDOT Transportation Asset Management Plan, Draft 05-02-14, pp 6.7 – 6.13.

Montana DOT

The Montana DOT TAMP lists as its first high-priority risk a decline in purchasing power caused by inflation, price volatility, and new mandates.[24] Other high-priority risks include extreme weather, a changing political climate that reduces support for asset management, and a "bubble" of asset-replacement needs if long-term needs are not addressed.

Transport Scotland

Transport Scotland, the roadway agency for Scotland, has incorporated risks into its TAMP since 2007. In the past, it has addressed risks such as inadequate asset data. The most recent 2016 TAMP focused on disruptions and threats. It emphasizes its emergency-response protocols as a strategy to mitigate risks to its trunk routes and other major facilities. It also emphasizes its slope monitoring and mitigation efforts, as well as flood-mitigation efforts. Both are a direct result of the higher storm frequency and severity it expects.[25] It highlights these risks as ones it intends to mitigate to preserve the condition and performance of high-risk assets on major trunk routes.

London Underground

The London Underground's asset management strategy incorporates risk as a core element.[26] It reports that because up to 50 percent of transportation service interruptions are caused by asset failure, asset management is a primary reliability strategy. It prioritizes assets based on the risks they present to safety and service delivery.

UK Road Liaison Group

The UK Road Liaison Group's *Highway Infrastructure Asset Management Guidance Document* cites asset management as a means to reduce risk, and it cites a focus on risk as a means to improve the management of assets.[27] By focusing on the greatest risks to asset condition and performance, agencies can better invest limited resources. At the same time, by keeping assets in Good condition, agencies reduce the risk to the public of safety or performance failures that will affect them. The liaison group's guidance incorporates risk into almost every area of asset management.

[24] Montana DOT Transportation Asset Management Plan, Dec. 2015, p 22.
[25] Transport Scotland, Road Asset Management Plan for Scottish Trunk Roads, Jan. 2016 pp 48-54.
[26] London Underground Asset Management Strategy Summary, 2013, accessed at http://content.tfl.gov.uk/lu-asset-management-strategy.pdf.
[27] UK Roads Liaison Group, Highway Infrastructure Asset Management Guidance Document, Department for Transport, London, 2013.

KEYS TO SUCCESS

Successfully integrating risk into asset management plans and processes revolves around several key attributes:

- The first key to success is high-level (top-down) support. Risk management works best when it supports executive decision making. A key to success involves convincing senior leadership of the value of methodically identifying risks and mitigating them, or capitalizing on them.
- Secondly, it is important to have a robust analysis that demonstrates the long-term consequences of investment scenarios. The impacts, or risks, caused by underinvestment grow geometrically over time as asset deterioration accelerates. Long-term forecasts that illustrate the future consequences of current actions are key to illustrating asset management risks.
- The third key involves a successful, risk-based, asset management program that includes trade-off scenarios illustrating which trade-offs reduce the greatest risks. An example could be an agency that accepts the risk of lower conditions in the early years of a TAMP to invest more in preservation, which may only provide higher conditions in the later years of the plan. Because funding shortfalls compel most agencies to make trade-offs, a robust scenario-analysis process allows agencies to determine which scenarios reduce the high-priority risks to asset conditions and performance.
- A fourth key factor is the presence of a successful risk-based, asset management process that addresses resiliency by anticipating and mitigating external risks such as increased storm events, seismic events, flooding, and other natural events.
- The fifth key to a successful program is the integration of risk into the agency's asset and performance management processes. Examples of integration include prioritizing asset investments based on risks surrounding asset classes, as done in Utah. Also, the review of risks and risk registers could occur with the periodic review of performance reports. Some agencies have monthly or quarterly performance reviews. When reviewing performance, agencies could also review risk registers to ensure risks are being managed and the agency's risk profile has not changed.
- A sixth key involves communicating risks and engaging stakeholders in the process. Share the agency's risk profile with the governor, legislature, media, and others. This sharing advises outside parties that the agency recognizes its risks and is trying to manage them, and that these risks could affect the performance outcomes that stakeholders expect. With the ongoing communication, external stakeholders can get a better understanding of the agency's risk and risk management process and be engaged more productively.
- The final element is continuous improvement of risk management skills and processes. Few agencies will begin risk efforts with much experience. Agencies can expect to continuously learn from their risk management efforts, and hopefully, continually improve. Staff skills can be developed, training can be sought, and the agency can document its successes and build on its experiences.

AVAILABLE RESOURCES AND REFERENCES

The following sources may be useful.

The AASHTO Guide for Enterprise Risk Management, First Edition, AASHTO 2016, available as an electronic document from the AASHTO Bookstore.

Risk-Based Asset Management Literature Review, FHWA-HIF-12-036, June 2012, accessible at the FHWA asset management website at https://www.fhwa.dot.gov/asset/pubs/hif12036.pdf.

Risk-Based Transportation Asset Management: Evaluating Threats, Capitalizing on Opportunities, Report 1: Overview of Risk Management, FHWA-HIF-12-035, June 2012, accessible at https://www.fhwa.dot.gov/asset/pubs/hif12035.pdf.

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Against the Gods: The Remarkable Story of Risk, Peter Bernstein, John Wiley and Sons, New York, 2006.