

Transportation Asset Management Plans

Case Study 4 – Managing Risks to Assets

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Case Study Introduction

This case study is one of seven that captures good asset management practices documented in the 2019 transportation asset management plans (TAMPs) required by 23 U.S.C. 119(e). This series distills many of the good practices and presents them in a convenient format for use by other transportation agencies.

The seven case studies are:

Case Study 1: Asset Management Practices and Benefits

Many of the TAMPs provided comprehensive summaries of their asset management practices and the benefits they received from them. Several examples are highlighted in this case study. These include examples from the DOTs in New Jersey, Pennsylvania, Illinois, and Washington State. These examples illustrate how asset management plans can effectively summarize asset management practices and improvement strategies.

Case Study 2: Linking Asset Management to Planning and Programming

This case study examines how TAMPs documented linkages to the DOT's long-range plan, the State Transportation Improvement Program (STIP), and state planning and programming practices. Examples are selected from the TAMPs in Missouri, Maine, Utah, Ohio, Wyoming, and Montana.

Case Study 3: Supporting Life-Cycle Planning

To develop a life cycle plan, one needs to know how assets deteriorate throughout their life cycle. Several TAMPs were notable in documenting how they manage assets with life cycle plans. Included in this case study are examples from the DOTs in Minnesota, Ohio, Tennessee, and New Jersey.

Case Study 4: Managing Risks to Assets

DOTs embrace risk management to support the long-term performance of assets, and for making risk-based investment tradeoffs. This case study summarizes some of the good risk management practices from Washington State, California, Kansas, South Dakota, Louisiana, Rhode Island, Pennsylvania, Texas, Colorado, and Michigan.

Case Study 5: Developing Financial Plans and Investment Strategies

The financial plans and investment strategies reflect priorities for allocating scarce resources to achieve their highest asset management objectives. This case study examines how several TAMPs described the clear linkages between their asset management objectives, gaps, risks, and investment strategies. Examples are from Kentucky, Michigan, Washington State, New York State, Utah, Vermont, and Illinois.

Case Study 6: Communicating Asset Management Strategies

This case study summarizes examples of communicating asset management strategies with key internal and external stakeholders. Examples are cited from the DOTs in Vermont, California, New Jersey, Washington State, Michigan, Ohio, Colorado, and Nebraska.

Case Study 7: Managing Non-Bridge-and-Pavement Assets

Several State TAMPs included additional assets beyond pavements and bridges. Examples are cited from Minnesota, Connecticut, Utah, and California.

Identifying and Managing Risks to Transportation Assets

Risk management is an important and expanding component of transportation asset management. The 2018 TAMPs laid out a path for risk management and the 2019 TAMPs described how States used risk management analyses to influence life-cycle planning and investment strategies, as well as to communicate with stakeholders. The TAMPs also enumerated the many risks facing States' asset management objectives.

The most common risks that appeared in TAMPs were as follows:

- Uncertainty over funding, and construction inflation
- Loss of skilled staff because of retirements, downsizing, low salaries, and competitive markets
- Weather and seismic risks
- Information and data gaps about asset condition, performance, and deterioration
- Lack of institutional or political support for the systematic, long-term investments needed to support life-cycle approaches
- Deteriorated assets whose investment needs exceed forecasted revenues
- Competing demands for capacity or economic development projects

This case study summarizes only a few of the insightful risk management references in the 2019 TAMPs and one brief example from a 2018 TAMP. All the plans are available on the FHWA website.

Risk Influenced All Chapters of the WSDOT TAMP

In the Washington State DOT (WSDOT) TAMP, risk analysis was supported by almost every section of the plan. The Asset Inventory and Condition chapter enumerated the asset classes and sub-groups that generated the greatest risks to the asset management objectives because of their poor condition or high cost to repair. The gap analysis discussed how gaps in local agency National Highway System (NHS) conditions exacerbated risks to achieving condition targets. The life-cycle planning chapter discussed what factors generated the greatest risks and opportunities to achieving the agency's life-cycle goals. The financial plan and investment strategies discussed how funds were allocated to mitigate the risks to the agency's asset management objectives.

Asset Inventory and Condition Chapter Highlighted At-Risk Assets

The TAMP chapter entitled Asset Inventory and Condition supported risk management by categorizing the assets that created the greatest risks to the asset management objectives. The TAMP stated that over 50 percent of the agency's asphalt pavements were more than 50 years old, which the TAMP stated was the typical design life. The TAMP indicated that a risk to those pavements was a lack of timely preservation, maintenance, and rehabilitation. The TAMP noted the pavements were not expected to fail or require reconstruction if they were treated correctly. A lack of funding or delayed treatments could create risks to the condition and performance of those aged asphalt pavements.

Also, the TAMP stated that 37.8 percent of the asphalt lane miles were chip sealed. Those thinly surfaced routes required prompt treatment at the appropriate points in their life cycle to keep them in good condition. Risks later identified in the TAMP included risks that could reduce or delay those timely treatments.

Another risk the TAMP noted was the 50 percent of the concrete lane miles that were more than 40 years old. They totaled about 1,000 lane miles, with 100 lane miles of concrete pavements more than 60

years old. The TAMP stated this was a risk WSDOT must manage immediately since concrete requires expensive replacement at the end of its useful life.

Overall, 13 percent of the network was concrete, 38 percent chip sealed, and 49 percent asphalt. The TAMP noted that each sub-group had its own risks to manage to achieve the objective of sustaining a state of good repair.

The chapter summarizing bridge and pavement assets stated that the most cost-effective and efficient approach to managing pavement assets was to have evenly distributed conditions among the Fair, Good, and Very Good categories with less than 3 percent of pavements in Poor or Very Poor condition. For its analysis, WSDOT subdivided the Federal measure for Good conditions into Good and Very Good categories and for Poor conditions into Poor and Very Poor. Although short-term condition indicators provided a snapshot of current conditions, the condition indicators did not inform WSDOT about the long-term risks or capture the impacts of long-term investments on the pavement network. The TAMP stated that the department managed its pavements with a long-term perspective to reduce the risks to sustaining a state of good repair.

WSDOT's bridge inventory description also detailed the attributes that created risks to sustaining the inventory in a state of good repair. Of the 3,913 structures in its inventory, 266 were 80 years old or older. Replacing them would cost nearly \$2.7 billion over the next 20 years, or about \$135 million per year in 2018 dollars.

WSDOT's performance goal was to maintain at least 90 percent of NHS bridges in Fair or better condition. In 2018, 92.5 percent of the Statewide inventory was Fair or better, while for the NHS 96.1 percent of bridge deck area was Fair or better, or 3.9 percent Poor based on the performance measures in 23 CFR Part 490.

Another WSDOT risk-related metric that could affect NHS performance was the number of load-limited structures. A total of 120 WSDOT-owned bridges longer than 20 feet were load restricted or posted at the end of 2018, up from 119 in 2017. Nearly half of those, or 57, were on the NHS and 33 of those were rated as Poor.

Gaps that Created Risks to Asset Performance Were Identified

The WSDOT TAMP noted that 23 percent of the State's NHS was managed by local agencies in partnership with Metropolitan Planning Organizations (MPOs). The TAMP stated that the local funding allocated for NHS bridges and pavements had a material effect upon the overall performance of the network. WSDOT identified gaps in the processes and information available to local NHS owners and gaps in the funding available to them. The TAMP stated that addressing those gaps to reduce risks to NHS condition and performance remained an ongoing effort with the MPOs and local NHS owners.

Risks to Life-Cycle Performance Were Managed

The characteristics of the bridge and pavement inventory that created risks were often the same characteristics that were the focus of the life-cycle planning chapter. By reducing those risks, the life cycles of the assets are extended and their performance increased.

Pavement Life-Cycle Strategies and Risks to Those Strategies Were Cited

The TAMP stated that when an asphalt pavement structure was laid, it was designed with enough thickness to carry expected traffic loads for 50 years if there were periodic surface renewals. WSDOT had found that these pavements can essentially be managed perpetually if they are monitored and resurfaced at the right time.

The TAMP stated that for asphalt pavements, resurfacing or rehabilitation was much more cost-effective than reconstruction, and avoiding expensive reconstruction was essential to reaching the department's State and 23 U.S.C. 150(d) pavement targets with its limited funds. The TAMP stated WSDOT had been able to avoid many reconstruction projects over several decades of pavement management by using timely treatments. Because WSDOT's asphalt pavements had experienced primarily top-down cracking, resurfacing had proven to be a cost-effective strategy that reduced expensive asphalt pavement reconstruction.

As a strategy to manage risks to long-term performance, the WSDOT plan stated that the agency documented through its pavement management system that applying preventive maintenance treatments early in the performance period had been highly effective. It estimated that for asphalt pavements, it saved \$15 million annually in maintenance costs with its timely, strategic treatment.

Although WSDOT adopted life-cycle strategies when it could afford their initial cost, one of the major risks the Washington TAMP documented was the lack of adequate funding, which prevented the agency from fully managing its pavements for the lowest life-cycle cost. The agency invested more in maintenance than it said was optimal and it indicated it was building up a liability of future rehabilitation costs. This documentation of growing risk and liability is one of the benefits of a TAMP and long-term financial planning in general, according to several publications.^{1,2,3}

The WSDOT TAMP illustrated the potential financial impacts of these funding risks. WSDOT converted pavement-treatment unit costs and the treatments' expected service life to an Equivalent Uniform Annual Cost, or EUAC. It was expressed as dollars per lane mile per year. The EUAC allowed treatments to be compared to determine which provided the targeted level of condition for the lowest annual cost. For example, a low-cost treatment such as chip seal that had a shorter service life could be compared to a more expensive treatment such as resurfacing.

The use of EUAC allowed WSDOT to evaluate the initial cost, expected service life, and risk to sustaining a state of good repair among different treatment strategies. The desire to achieve condition targets while constraining budgets and managing risks led WSDOT to a mix of fixes that improved conditions but also highlighted risks to the pavement performance. Unless treatments were timely, the window of opportunity for preservation passed, more expensive treatments were needed, and the agency faced higher life-cycle costs.

WSDOT relied heavily on chip seals instead of more expensive asphalt treatments on its low-volume, largely rural roadways. WSDOT determined that, under the right conditions, pavements with chip seal surfacing were more cost-effective than pavements with an asphalt surface. This was because the overall life-cycle cost of an asphalt pavement was roughly 2.5 times the life-cycle cost of a chip seal pavement. Because of this cost savings, it had been a priority of WSDOT to resurface using chip seals where appropriate. This was typically appropriate for road locations having less than 10,000 Annual Average Daily Traffic (AADT), which were not in an urban area, and where trucks did not turn frequently. Under these criteria, a substantial number of sections that were, or have traditionally been, managed with an asphalt resurfacing strategy were candidates for chip seal. When a chip seal was placed on existing asphalt pavements, WSDOT referred to this as "chip seal conversion."

WSDOT had used chip seal conversion for approximately 2,300 lane miles between 2010 and 2017, and the lane mile percentage changed from 25 percent chip seal to 38 percent of the State system. WSDOT planned to convert at least another 700 lane miles over the next five years. At that point, chip seal surfacing would have accounted for approximately 40 percent of the State-maintained network. Therefore, the major effects of this strategy on the annual network cost was to shift 3,000 lane miles

from asphalt to chip seal resurfacing by 2024, and result in an annual savings of over \$40 million per year.

However, WSDOT's risk register noted that any delay to the timeliness of pavement treatments represented a risk to the continued achievement of the life-cycle cost saving, which was particularly true for the thin chip seal treatments. The TAMP stated WSDOT was trying to mitigate these risks through improved procedures to make project programming more accurate. Another related risk was the lack of preventive maintenance treatments applied at the proper point in the pavement's life cycle. The mitigation for this risk was to develop consistent maintenance implementation strategies across all the Districts. A third risk was the use of studded snow tires, which was legal in Washington. The mitigation for that risk included communicating the damage that studded tires did and supporting legislation to ban their use. Insufficient funding was another pavement program risk. To save money over the pavements' life cycle, money was spent initially on the timely chip seals and the rehabilitation treatments when they are needed. Insufficient funds to treat the pavements at the right times not only lowered pavement conditions but also created more long-term costs.

For concrete pavements, WSDOT in recent years relied on treatments such as dowel bar retrofits, diamond grinding, and selective slab replacement to extend their life to 40 years or more. With an increasing number of concrete lane miles that could no longer be sustained with those treatments, the TAMP stated WSDOT faced the challenge of addressing the 1,000 lane miles of aging concrete pavements economically. The TAMP stated to rehabilitate them with the lowest life-cycle cost, WSDOT would rely largely upon crack, seat, and overlay treatments, although concrete replacement would be needed in high-traffic sections.

The TAMP stated that managing the aging concrete sections was one of WSDOT's major pavement risks. To further mitigate the risks, WSDOT committed to evaluating concrete activities over the next six years as it invested funds from an increased revenue package. The TAMP stated that how WSDOT decided to manage the risk from the aging concrete pavements could leave the risk as fully, or only partially, mitigated.

The WSDOT TAMP stated that by 2025 the agency would save \$80 million annually in pavement costs with its life-cycle planning strategies compared to strategies deployed prior to 2010. Risks to sustaining those savings while meeting condition targets included the need for adequate funding to maintain the preservation treatment cycles, coordinating the timely treatments with the Districts, dealing with the effects of unexpected pavement failures, and the damaging effects of studded snow tires.

TAMP Identified Bridge Life-Cycle Strategies and Risks to Those Strategies

The TAMP stated WSDOT was working to develop methods, analytical tools, and long-term measures to forecast bridge life-cycle performance. WSDOT was implementing bridge management system software and was on track to deploy it by March 2021. This would allow WSDOT's Bridge & Structures Office to assign costs to existing risks, as well as to assign monetary value to efficiently prioritize the WSDOT bridge inventory for timely repair, rehabilitation, and replacement.

WSDOT deployed a series of maintenance treatments and preservation strategies to reduce the life-cycle cost of bridges including bridge cleaning, steel beam painting, concrete deck overlays, scour mitigation, element repair and replacement, and when economically justified, bridge replacement. WSDOT also had invested about \$200 million in seismic retrofit projects.

While many of the pavement risk strategies focused upon lowering the risk of higher costs, many of the bridge risk management strategies focused upon preventing premature or catastrophic bridge failure. Identified bridge risks included insufficient funding that could lead to premature failures, flooding and

scouring, vehicle strikes, and risks from earthquakes. One risk that could have increased the life-cycle cost of managing bridges was poor construction quality. Another risk that indirectly would increase bridge life-cycle cost was the loss of trained staff.

Investment Strategies Were Intended to Achieve Objectives and Mitigate Risks

WSDOT conducted four investment strategy scenarios each for bridges and pavements. The primary performance measures that were measured in the scenarios were the condition levels and what WSDOT called Deferred Preservation Liability, or DPL. The deferred preservation penalty was a unit assigned for each year in which a pavement preservation treatment was applied other than the Preferred Construction Year recommended by the Washington State Pavement Management System (WSPMS.) A similar Deferred Preservation Liability unit was assigned for each year a bridge did not receive the treatment it was recommended to have. Four scenarios were conducted: 1) no build or no expenditures, 2) current investment levels, 3) minimum investment levels, and 4) \$500 million less than current investment levels.

The analysis showed that current funding was adequate to sustain conditions for 4 years, but not for 10. Overall, the scenarios confirmed the preservation funding gap was large and WSDOT needed to act in the near term to address the gap. The TAMP stated WSDOT had, and would continue to, communicate the size of the gap to the Legislature and Governor.

The TAMP stated that with an objective of sustaining conditions in a state of good repair while working with insufficient funding, the investment strategies sought to reduce future liability in terms of deteriorated conditions and backlogs of costly investment. Project prioritization considered asset uses, life-cycle costs, and avoiding future liability. If deferral of a treatment created a future liability, it became the highest priority. The prioritization attempted to avoid assets falling into such disrepair that worst-first approaches were needed or would leave the assets in poor condition.

Using “Avoiding Future Liability” as the highest priority resulted in WSDOT prioritizing funding for crack sealing, chip sealing, chip seal conversions, and any project that reduced the need for near-term pavement reconstruction. Also factoring into the strategy was asset use with more priority given to projects on high-truck-volume routes, and priority given to projects that reduce an asset’s life-cycle cost.

The TAMP stated that insufficient preservation funding would create condition performance gaps over the 10 years of the plan and accumulate a large amount of liability to restore the assets to a state of good repair. WSDOT was not able to address that gap with then-current funding levels. The investment strategies the agency adopted attempted to reduce the future backlog and liability until the preservation investments could be increased.

California DOT Worked with Partners to Manage Risks

The California Department of Transportation (Caltrans) 2019 asset management plan illustrated the wide range of risks that affected asset conditions and how agencies can benefit from coordinating with other Federal, State, and local partners to manage them.

Out of 56,075 lane miles on the NHS in California, 19,427 were owned by local agencies, or 34.6 percent of the total. The Southern California Association of Governments (SCAG) alone controlled 11,658 lane miles of the NHS, more than some States manage.

The risk efforts summarized in the Caltrans TAMP reflected the distributed nature of the highway system, the State’s large size, its diverse topography and climate, its extensive coast, and its seismically active geology. The TAMP noted that the 1994 Northridge earthquake killed 57, injured 8,000 and

leveled portions of Interstate 5 while damaging many other highways. In 2017, a landslide along coastal Highway 1 buried the road under 1.5 million tons of rock and mud closing the highway for months. Fires had become a near constant threat that often threatened the highway infrastructure.

The Caltrans TAMP stated the agency established the Office of Enterprise Risk Management in 2013 to perform biennial enterprise risk assessments and to consult with internal clients. As part of that work, Caltrans developed an Enterprise Risk Profile every two years using the *International Standards Organization (ISO) 31000 Risk Management Standard*. Caltrans identified the risks by District or program and evaluated the likelihood and impact of each risk. Caltrans also had management approaches for project delivery risks, information technology security risks, emergency risks, and safety risks. Caltrans' risk management approach was codified in handbooks, State guidance, and tools. The Office of Enterprise Risk Management evaluated asset management risks as well as other Caltrans risk areas.

The TAMP stated Caltrans also participated in a multi-agency effort known as Safeguarding California. Safeguarding California identified, assessed, and mitigated climate change risks across the State. The statewide transportation strategies summarized in the TAMP included:

1. Understand climate trends that impact transportation.
2. Complete analysis of vulnerability assessments and prepare adaptation plans to address identified vulnerabilities.
3. Inform the transportation decision-making procedures.
4. Improve transportation system resiliency.
5. Maintain and enhance information sharing and education.

The TAMP stated Caltrans conducted vulnerability assessments and adaptation reports for all 12 Districts. This effort used the most recent climate models and analysis methods. By 2020, the TAMP stated, Caltrans intended to complete prioritization of the vulnerable portions of the State highway system within each District. Climate stressors to the system include flooding, landslides, sea level rise, washouts, pavement deterioration, increased wildfires, and the buckling and rutting of roads due to extreme heat. The regional transportation assessments considered the exposure of transportation assets to climate stressors as well as their criticality, or relative importance, based on use, stakeholder input, health and safety functions, and replacement costs.

The TAMP stated Caltrans supported adaptation research and pilot projects, including a study of State Route 37 in the San Francisco Bay Area, a green infrastructure study on State Route 1 at Elkhorn Slough in Monterey, and adaptation plans in Humboldt County for Highway 101. To promote information sharing and education, Caltrans convened and participated in climate adaptation workshops with local, regional, and Federal partners, academia, and other transportation stakeholders. Caltrans also created an Integrated Planning Team with the California Coastal Commission to coordinate policy implementation between the agencies.

Caltrans Programs Help Mitigate Local NHS Risks

The Caltrans TAMP summarized how several Caltrans programs supported the TAMP risk-mitigation efforts by directing funds or non-monetary support to both the State-managed NHS and locally managed NHS to reduce risks caused by weather or seismic-related threats. The following examples were summarized in the Caltrans TAMP.

The Caltrans TAMP noted the Seismic Safety Retrofit Program, created in the wake of widespread bridge failure during the 1989 Loma Prieta earthquake, identified and retrofitted existing State highway bridges to comply with current seismic safety standards. The TAMP indicated that as of 2017, the program had

completed the retrofit of 2,202 of the 2,203 State highway bridges with identified seismic vulnerabilities at a cost of more than \$12.2 billion.

The Caltrans TAMP stated the Local Bridge Seismic Safety Retrofit Program was established to provide funding assistance for public bridges owned by local agencies to achieve compliance with current seismic safety standards. As of October 2017, seismic retrofit work had been completed on 310 of the 376 bridges with identified seismic vulnerabilities.

The Caltrans TAMP also noted the Local Highway Bridge Program funded the replacement or rehabilitation of locally owned public highway bridges. Roughly \$300 million of Federal funds were made available to local agencies annually for work including replacement, rehabilitation, painting, scour countermeasure, bridge approach barrier and railing replacement, low-water crossing replacement, ferry service replacement, and preventative maintenance activities.

The Caltrans TAMP also stated the Local Bridge Preventive Maintenance Program was part of the Local Highway Bridge Program and paid for preventive maintenance activities. The purpose of the program was to maintain bridges in Good or Fair condition, mitigating the risk of accelerating bridge deterioration and rising costs. By completing preventive maintenance activities, local agencies could extend the service life of their assets and reduce costs over the life cycle of the assets.

In addition to the risks already cited, Caltrans for its TAMP risk management analysis conducted in response to 23 CFR 515.7(c) an assessment of risks to the TAMP and its objectives. The scope, scale, and diversity of those risks cited in the TAMP's risk management section further illustrated the close links between asset management and other objectives, such as highway safety and asset resilience.

The TAMP risk management discussion indicated that the highest ranked risk was failing to adequately plan for extreme weather impacts. The TAMP risk mitigation strategies included accelerating the Safeguarding California strategies, addressing identified vulnerabilities, compiling needed data for impact modeling, and ensuring that drainage system cleaning occurs.

Caltrans TAMP Also Addressed Project Delivery, Human Resource, and Information Risks

Although many agencies noted uncertain revenue as a risk, the Caltrans TAMP noted the department received a large revenue increase that created its own set of risks. The Caltrans TAMP indicated that one risk was that Caltrans needed to substantially increase its project-development efforts to quickly make use of the needed funds. The TAMP risk section mitigation strategies included innovative contracting, increased staffing levels, and improved communication to the legislature about the performance management efforts included in the TAMP. Another risk the Caltrans TAMP included was that the increase in State funds could result in project-delivery backlogs that would lead to not using all its Federal-aid funds and losing the annual redistribution of Federal funds.

A related risk included in the Caltrans TAMP was if the Regions were unable to use innovative project delivery tools, it would take longer than optimum to invest the new revenues. Further complicating delivery of asset management projects, the TAMP noted, was the frequent tendency to make projects more complex by adding amenities that while requested, increased project development times and delayed needed treatments.

Like with many other States, the Caltrans TAMP identified human resources as a risk to assets. If employees were not trained and mentored, Caltrans feared knowledge gaps. A related risk in the TAMP was if the agency did not conduct succession planning, it would lose agency knowledge. TAMP risk mitigation strategies in response included broadening and accelerating training.

Another common risk included in the Caltrans TAMP was risk to information and decision making. One risk the TAMP included was if the agency did not have reliable asset performance models, its investment decisions would not be optimal. A related risk was if the agency did not incorporate climate impacts into its performance models.

Kansas DOT Adopted a Road Map to Manage Risks

The Kansas Department of Transportation (KDOT) 2018 asset management plan demonstrated how an agency can develop a road map for establishing a risk management program. The 2019 fully compliant KDOT plan illustrated that the agency deployed the roadmap to manage its risks.

The 2018 TAMP said that while risk management was not new to KDOT, the asset management plan offered an opportunity to strengthen and establish more structure around the process. Although KDOT adopted the 23 CFR 515.7(c) FHWA framework that is similar to the International Organization of Standards 31000 risk framework, the TAMP stated KDOT's implementation would be agile in nature with frequent reassessment of the process and redesign as necessary.

The 2018 TAMP developed a risk register organized into three categories of risks: system/internal risks, financial risks, and external risks. For the 2018 TAMP, KDOT used some simplified definitions of likelihood and consequence and tasked the risk team to develop more refined ones for the 2019 fully compliant TAMP. The risk management team was tasked with defining risk levels based on the comparison of likelihood and consequence and use the levels to prioritize the risks based on the criteria defined in the risk management framework to identify potential risk-response options. Risk levels and response options were to be brought into alignment with the risk management policy and the defined risk appetite/tolerance that informed the risk management framework.

The 2018 TAMP stated that KDOT's intent was to ultimately have a refined risk register that would be used to summarize KDOT's risks, the analysis process, and the response options. Risk registers would also identify risk owners accountable for monitoring and managing the risks they were assigned. It was important to track the progress of risk responses to learn lessons to apply to other potential risks, identify newly emerging risks, and generally ensure that risks related to the asset management process are appropriately managed.

The 2019 TAMP stated an early step during the development of the 2019 TAMP was convening a risk management team. This team consisted of members of the agency's leaders guided by the project management team. Out of this team, KDOT said it would identify the person(s) responsible for developing, implementing, and maintaining the risk management framework and products; identify risk owners who would be accountable for risk response and treatments; and identify the risk management responsibilities of others throughout the organization. Risk owners were to be assigned following the general structure defined in the Guide for Managing Risk Across the Enterprise developed through National Cooperative Highway Research Program (NCHRP) project 08-93. That guide recommended managing risk at the enterprise, program, project, and activity levels. With a team assembled, KDOT said it would define a risk management policy that outlined linkages with KDOT's strategic goals and asset management objectives, formalize the accountabilities for managing risk, and demonstrate an organizational commitment to managing risk.

In 2019 the TAM Steering Committee established a risk management framework that identified a governance structure with goals and priorities for risk management, defined the scope of risk management at KDOT, and established risk criteria and tolerance levels. This process culminated in a

workshop where the Risk Management Team identified and analyzed 35 risks, including 10 with high priority.

The 2019 KDOT TAMP included the following goals for the risk management process that were not included in the 2018 TAMP:

- Reduce any risk of harm to stakeholders.
- Improve asset management decision making by incorporating risks.
- Reduce major risks to maintaining pavement and bridge assets in a state of good repair.
- Support achievement of the asset management objectives and performance targets.

As the process matured between 2018 and 2019, the risk categories became more numerous and specific. For the 2019 TAMP, risks were identified in the categories of asset performance, safety, business operations, external/reputational, financial/economic, information technology, legal and compliance, or workforce/organizational.

The 2019 process also benefited from refined definitions for consequences. Definitions were provided for what was meant by consequences that are negligible, minor, major, severe, and extreme. The definitions were specific for the eight categories. For example, a negligible risk to asset performance was that there would be little to no deterioration or damage to assets, while a severe consequence was major deterioration or damage to assets on highway systems causing travel disruptions for an extended time.

The highest priority risk was deferred maintenance that would lead to increased deterioration, increased vehicle operating costs, and increased costs to maintain the highway network. The mitigation strategies were to enhance data collection, improve pavement designs, and seek authorization to use Federal funds for light preservation treatments.

Other high priority risks were a loss of institutional knowledge, uncertain funding, increased freight traffic, slowdowns in the procurement process, cyber threats, inability to keep pace with technological changes, bridge failure, increase in fuel prices, and bridge damage by vehicle impacts.

South Dakota DOT Used a Risk Matrix to Assess Sites of Repeated Damage

The South Dakota Department of Transportation (SDDOT) 2019 asset management plan included the unique use of the agency's risk matrix to evaluate sites that had been repeatedly damaged by emergency events. State DOTs were required by 23 CFR Part 667 to conduct statewide evaluations to determine if there are reasonable alternatives to roads, highways, and bridges that have required repair and reconstruction activities on two or more occasions due to emergency events. Although every State conducted the Part 667 analysis, SDDOT included an additional step that was not seen in other TAMPs. This additional step was to use its likelihood and consequence matrix to evaluate the sites. The result of SDDOT's use of its likelihood and consequence matrix was to provide a comparison between the risk facing each site to prioritize them. This use of the likelihood and consequence matrix appeared to be unique among the 52 2019 TAMPs.

The evaluation identified 13 sites that had been repeatedly damaged, four of them on the NHS. South Dakota has what are called "prairie potholes" which are closed drainage basins. Seven repeat projects involved grade raises through these closed basins and riprap protection to prevent damage to the roadway due to wave action and ice from rising water elevations. Another four sites experienced scour

at river crossings that had to be remediated. In addition, repeated repairs were performed on a dam and on a landslide site. Each site had been returned to service and mitigated to keep it in service and was not determined to be of high hazard. Based on the likelihood and impact of each site, all were rated as low risk except one slide area that was rated as moderate.

Louisiana Emphasized Large, Aging Bridges as High-Risk Assets

Being a low-lying coastal State, Louisiana had a large inventory of bridges, some of which were inordinately large structures. This created financial and condition risks for the agency. The 2019 Louisiana Department of Transportation and Development (LaDOTD) TAMP was one of the few that singled out a specific asset sub-group as a major risk. The benefit of singling out the most at-risk asset sub-group is that it brings clarity to which type of investment strategy is needed to address this major risk.

The LaDOTD 2019 TAMP stated that of 7,878 bridges, 123 had more than 175,000 square feet of deck area. The 123 represented only 3.6 percent of the total NHS bridges but comprised 57.7 percent of the total NHS bridge deck area and total more than 79 million square feet of deck area.

LaDOTD recognized the issues that these critical, large, outlier bridges posed, but with the ongoing fiscal limitations, funding was not available to immediately deal with this. The TAMP stated that LaDOTD would make every attempt to avoid a worst-first approach going forward. However, the TAMP stated the outcome of both historically limited funding, along with the significant deck area of outlier bridges, had placed LaDOTD in a precarious position. The TAMP stated the preservation needs of these very large, critical bridges continued to mount and could not be ignored. Repairing or replacing these large bridges would continue to consume all necessary funding to maintain them in a safe and effective manner. The TAMP stated the concept of allowing a few assets to continue to decline while spending available funding on preservation of many assets could not be applied in these extraordinary cases.

The TAMP stated that in the past few years, a few large critical outlier bridges had consumed significant available preservation funding. In many cases, these projects involved multiple phases over several years simply to compile the necessary funds. The multiple phases increased the overall project cost, but it was necessary when funding was not available in a single year. The TAMP stated LaDOTD could not spend all available funding each year on a single project.

The TAMP stated that when long-term funding issues were resolved, LaDOTD would provide additional dedicated funding for these outlier bridges. Until then, each of the NHS outlier bridges would have the potential to impact LaDOTD's achieving NHS bridge performance targets and state of good repair goals.

Risks to Asset Resilience Were Increasingly Managed

The 2019 asset management plans demonstrated that agencies increasingly were taking steps to assess and manage risks caused by extreme weather, seismic events, and other external threats. The emphasis upon such risks was frequent in coastal and mountainous States but also was evident in inland States such as Pennsylvania.

Rhode Island DOT Developed a Sea Level Rise GIS Tool

The 2019 Rhode Island Department of Transportation (RIDOT) TAMP noted 400 miles of coastline and large inland watersheds make the State vulnerable to hazards such as sea level rise, storm surge, and

flooding. The TAMP stated that in response to these threats, RIDOT participated in the development of a GIS tool called STORMTOOLS. The models and maps in STORMTOOLS allowed illustration of the risks of coastal inundation under different sea level rise scenarios. The TAMP stated that for coastal roads and bridges, even a foot of sea level rise could result in flooding and structural problems. The impact of sea level rise was even more pressing given the many storm drain outfalls that were near sea level. Significant sea level rise would swamp outfalls and cause the drains to fail. STORMTOOLS allowed RIDOT to consider the effects of sea level rise in the future as it designed bridges that may remain in service for much of the next 100 years. The Rhode Island TAMP stated by 2050, a point at which the new bridges of today would be about halfway through their lifecycles, sea levels may have risen 3 feet or more. The development of an environmental resiliency tool would allow RIDOT to plan and design for this risk.

Pennsylvania DOT Noted Efforts to Reduce Flooding Risks

The 2019 Pennsylvania Department of Transportation (PennDOT) asset management plan stated that flooding represented its most common weather- or climate-related risk. PennDOT conducted an Extreme Weather Vulnerability Study that produced a geographic information system (GIS) tool that highlighted potential flood risks. The Road Condition Reporting System (RCRS) was used to identify locations of flooding vulnerabilities. The TAMP stated the GIS tool included a map of all the flooding sites with each site ranked by whether it was in the top 1 percent, 5 percent, 10 percent, 15 percent, 20 percent, or 25 percent of the vulnerable sites. Data for each site included the number of times it had been closed because of flooding, its AADT, and risk prioritization score. The TAMP stated that PennDOT also conducted a pilot in three counties to identify sites' future potential for flooding given precipitation projections.

The TAMP stated that PennDOT also formed a Resiliency of Design Task Force. It intended to identify steps to reduce the risk from extreme weather events by enhancing engineering, design, construction, and maintenance practices. The TAMP stated PennDOT anticipated updating its hydraulics manual and recommending practices to reinforce embankments, increasing culvert and pipe sizes, updating bridge scour countermeasures, and modifying wingwalls.

Texas DOT Analyzed Hurricane and Flood Risks

The 2019 Texas Department of Transportation (TxDOT) asset management plan identified NHS lane miles and bridges at risk of both inland flooding events and storm surge. The identified structures could be prioritized for analysis after events, and the information about their potential risk could inform the planning and programming processes.

The plan stated that 367 miles of Texas coastline are on the Gulf of Mexico and would be vulnerable to storm surges. The TAMP stated that Hurricane Harvey in 2017 produced the largest historical rainfall in a single event in the State's history and that this type of extreme weather event posed the predominate threat to Texas infrastructure. TxDOT analyzed the extent of inundation predicted by hurricanes between category 1 and category 5 based upon data from the National Oceanic and Atmospheric Administration (NOAA.) The storm surge levels were overlaid on the NHS network to determine the extent of the NHS affected by the different levels of events. For a category 1 hurricane, 359 lane miles of NHS roadways could be inundated with the lane miles increasing to 2,681 for a category 5.

Analyzing inland areas, TxDOT estimated the NHS lane miles possibly affected by 100-year and 500-year flooding events. Within the flood plains of 100-year events were 4,811 lane miles while 5,753 lane miles were within flood plains that could be affected by 500-year events. The TAMP stated that every vulnerable site might not be damaged if inundated, and assessment would be done after an event.

TxDOT analyzed the number of bridges within 100-year and 500-year flood plains which crossed water and had a National Bridge Inventory (NBI) item 113 rating for scour susceptibility of 4 or less. The analysis showed that while only 2 percent of the State NHS structures met those criteria, it resulted in 132 NHS bridges vulnerable to either a 100-year or 500-year event. The TAMP stated TxDOT had made changes to reduce bridge scour from flood-prone areas and bridge heights were increased to address potentially higher storm surge. Programmatically, resilience efforts for riverine and coastal areas were included in planning and programming when assets needed repair, rehabilitation, or reconstruction.

Colorado DOT Analyzed Risks to Resilience

The Colorado Department of Transportation (CDOT) 2019 TAMP included at least four risk innovations not seen in other States' asset management plans.

First, the TAMP stated CDOT was building from a demonstration project assessing risks to the Interstate 70 corridor through the Rocky Mountains. It is the only multi-lane artery across the Rockies in Colorado, and its closure would result in extensive detours. CDOT assessed the corridor using the Risk Analysis and Management for Critical Asset Protection (RAMCAP). The RAMCAP process was developed after the terrorist attacks of September 11, 2001 and was developed to assess physical assets' vulnerability to threats either manmade or natural. It took factors such as estimated likelihood of an event multiplied by the financial impact of the event to develop an expected value of the cost of the risk. The expected value of different risks to different assets can be compared with the common denominator being the cost of the risk. Preventive steps could "buy down" the risk cost. If an action reduced the probability of risk from 1.0 percent to half of 1.0 percent, the expected value falls from \$1 to \$0.50. CDOT assessed the annualized costs of risks to the I-70 corridor from avalanches, floods, fires, rockfalls, landslides, and high winds. CDOT's TAMP stated the agency hoped to develop risk data for other State highways in Colorado, like what the pilot project produced for I-70.

Second, CDOT added the concept of vulnerability along with likelihood and consequence when assessing risks. The formula was not just Likelihood X Consequence but was: Risk Score = Threat X Consequence X Vulnerability. The 2019 CDOT TAMP equated "threat" with "likelihood" based upon the degree of a threat equated to the degree to which the threat event was likely to occur. The TAMP defined vulnerability as a measure of existing risk management strategies' ability to withstand an event. The TAMP stated that compared to the previous method of ranking risks only by likelihood and consequence, the new method resulted in a wider range of scores offering more precision in ranking events. It also provided the ability to measure the effect of alternative risk management strategies. Specifically, it improved comparison of how various risk management strategies could potentially lower the risk profile of an asset.

Third, consequences were evaluated from four perspectives, and values were assigned. The four consequences were safety, mobility, asset damage, and other financial impacts such as to a community. Therefore, a consequence value could be the product of the multiplication of the safety value, mobility value, asset damage value, and other financial impact values.

Fourth, CDOT was developing a process to incorporate considerations of risk into project selection and prioritization. The criticality of each asset to be programmed for improvement was to be assessed based upon the AADT, roadway classification, freight volume, tourism importance of the route, whether the route lacks redundancy, and its social vulnerability. Social vulnerability was a measure at the county level of the importance of the facility to the county's social well-being. If the location had been damaged before by a flood, rockfall or other event, the site would be evaluated for risk-management steps as part of the scope for the project. If a site that had been previously damaged was programmed for a project,

then an asset-specific risk register can be developed for the site, and alternative risk mitigation strategies can be analyzed as part of the planning and design process.

Michigan DOT Takes Steps to Mitigate Risks to Staff Expertise

Many of the 2019 TAMPs listed as a high risk the loss of expert staff. Because of retirements, downsizing, and the unique skills needed for managing assets, many States reported that lacking experienced asset managers was a major risk.

The Michigan DOT TAMP was one of the few to include a mitigation strategy for this risk. The 2019 TAMP stated MDOT had undertaken several measures intended to retain institutional knowledge, such as process documentation. Also, to retain talent, MDOT noted it is undergoing a multi-year plan to reinvigorate MDOT culture through the Workforce and Succession Planning System, a program referred to as “The House” that is made up of five pillars, including knowledge management. MDOT recently had hired an organizational development officer who was to be consolidating and strengthening the department’s capabilities around recruitment, training, employee development, and organizational performance. This effort was targeted toward improving MDOT’s recruitment and retention efforts.

Additionally, there is a group tasked with determining what future job type or classifications are needed to support MDOT in a rapidly changing environment.

¹ FHWA, Developing TAMP Financial Plans, Final Document, November 17, p 2

² FHWA, Incorporating Risk Management into Transportation Asset Management Plans, Final Document, November 17, p.17.

³ Kavanaugh, S., M. Han Na, Long-Term Financial Planning for Local Government, the Government Finance Officers Association, 2008, p v.