Chapter 6
Monitoring and Adjustment

Section 6.1
Monitoring Performance Measures
describes the role of performance data to drive investment decisions and methods to evaluate the effectiveness of performance measures and targets.

Section 6.2
Monitoring the State of Assets
summarizes the types of information needed to support performance-based decisions.

Section 6.3
Monitoring Funding and Resource Allocation Methods
describes the types of funding and resource allocation methods commonly used and how the information can be used to make program adjustments.

Section 6.4
Monitoring Asset Work and Costs
addresses the importance of tracking work activities and how the data can be used to improve models.

Section 6.5
Monitoring Risks and TAM Processes
identifies tools and processes used to track and manage risks and other TAM processes.

Chapter 6
Monitoring and Adjustment

TAM relies on the continued availability of reliable and comprehensive data to support decisions. This chapter addresses the need to monitor and adapt TAM data and business processes to stay relevant.

Key Terms

Goals
See Chapter 2

Level of Service
The defined performance for a particular activity or service area.

Measures
Indicators that track progress toward goals and objectives. Used to establish targets and assess progress toward achieving established targets. (TPM Guidebook).

Objectives
See Chapter 2

Performance
A quantitative or qualitative outcome. For transportation assets, performance is usually described in terms of condition, but it may also represent operational characteristics.

Performance-Based Decision Making
The use of performance data to guide agency decisions.

RACI
An acronym for a type of responsibility matrix that clarifies who is responsible for a task, who is accountable for the task, who needs to be consulted, and who needs to be informed. This approach is described in Section 6.5.

Risk
The positive or negative effects of uncertainty or variability upon agency objectives. (from 23 USC 515.6).

Risk Management
See Chapter 2

SMART
An acronym commonly used for evaluating performance targets to determine whether they are specific, measurable, achievable, relevant, and time-related.

Targets
See Chapter 2

Transportation Performance Management (TPM)
A strategic approach that uses system information to make investment and policy decisions to achieve national performance goals (as defined by FHWA).

Section 6.1

Monitoring Performance Measures

Performance measures are used by transportation agencies to align agency investment decisions with organizational objectives, such as asset condition or system reliability, and to monitor progress towards achieving agency goals. In TAM, asset performance is most commonly defined in terms of asset condition, but performance can also be represented by operational considerations, such as safety or traffic reliability.

This section has two parts:

1. **Selecting and Using Performance Measures.** The importance of selecting performance measures that support agency decisions is presented along with examples of how performance measures can be used.
2. **Evaluating the Effectiveness of Performance Measures.** This part introduces processes to evaluate the effectiveness of performance measures in a continually changing world.

Selecting and Using Performance Measures

This section discusses the importance of using performance data to make decisions. It highlights the role of performance measures and identifies how they are used to establish achievable performance targets. A more detailed discussion of Transportation Performance Management can be found in Chapter 2.

Performance Management Framework

As discussed in Chapter 2, transportation agencies have embraced the use of performance data to drive investment decisions. A performance-based management approach enables agencies to select and deliver the most effective set of projects for achieving strategic objectives, while also improving internal and external transparency and accountability.

A typical performance management framework includes:

- A clear idea of the agency's strategic objectives.
- The use of performance measures to assess performance.
- Methods to evaluate and monitor performance results.
- The evaluation of factors with capacity to improve long-term performance.
- The allocation of funding to achieve agency objectives.
- Ongoing processes to monitor and report progress.

A fundamental component of the framework is the use of performance measures to evaluate system performance and the importance of establishing business processes to evaluate, monitor, and use the data to influence agency decisions. These are achieved by aligning decisions at all levels of the organization with the agency's strategic objectives and ensuring that the right performance measures are being used to drive decisions. This alignment helps to ensure that resource allocation decisions and the day-to-day activities of agency personnel support the agency's priorities and the interests of external stakeholders.

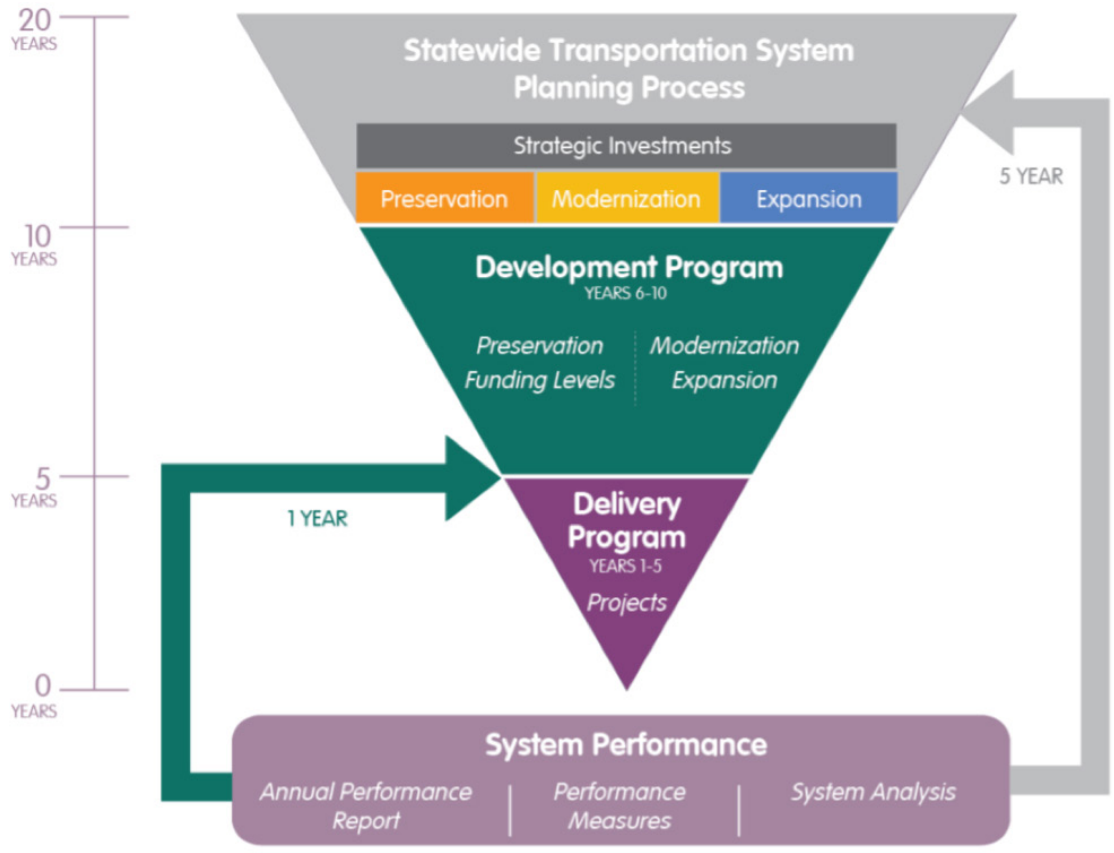
Practice Example
Aligning Investments With Strategic Objectives

Arizona DOT

In 2001, during the development of a long-range transportation plan (LRTP), the Arizona DOT took a strategic approach to how investments should be made. Under the new approach, Arizona DOT established the following three investment categories:

- Preservation, including activities that preserve existing transportation infrastructure.
- Modernization, including improvements that upgrade the efficiency, functionality, and safety without adding capacity.
- Expansion, including improvements that add transportation capacity by adding new facilities or services.

To implement the new initiative, the Arizona DOT developed a report titled "Linking the Long-Range Transportation Plan and Construction Program" or" P2P Link" that applied financial constraints to the long-term vision. Through a collaborative process that involved a consultant, local and regional governments, and transit agencies, the Arizona DOT published an implementation plan for putting the P2P Link into practice. The resulting process includes scoring projects based on both a technical and policy score that are added together to determine a project's ranking. The technical score is generated by the asset owner based on an analysis of the data while the policy score is determined based on each project's contribution to LRTP goals and performance measures. The process helps to ensure that projects are ranked in accordance with the agency's strategic objectives using only the most meaningful criteria in a transparent and defensible way.



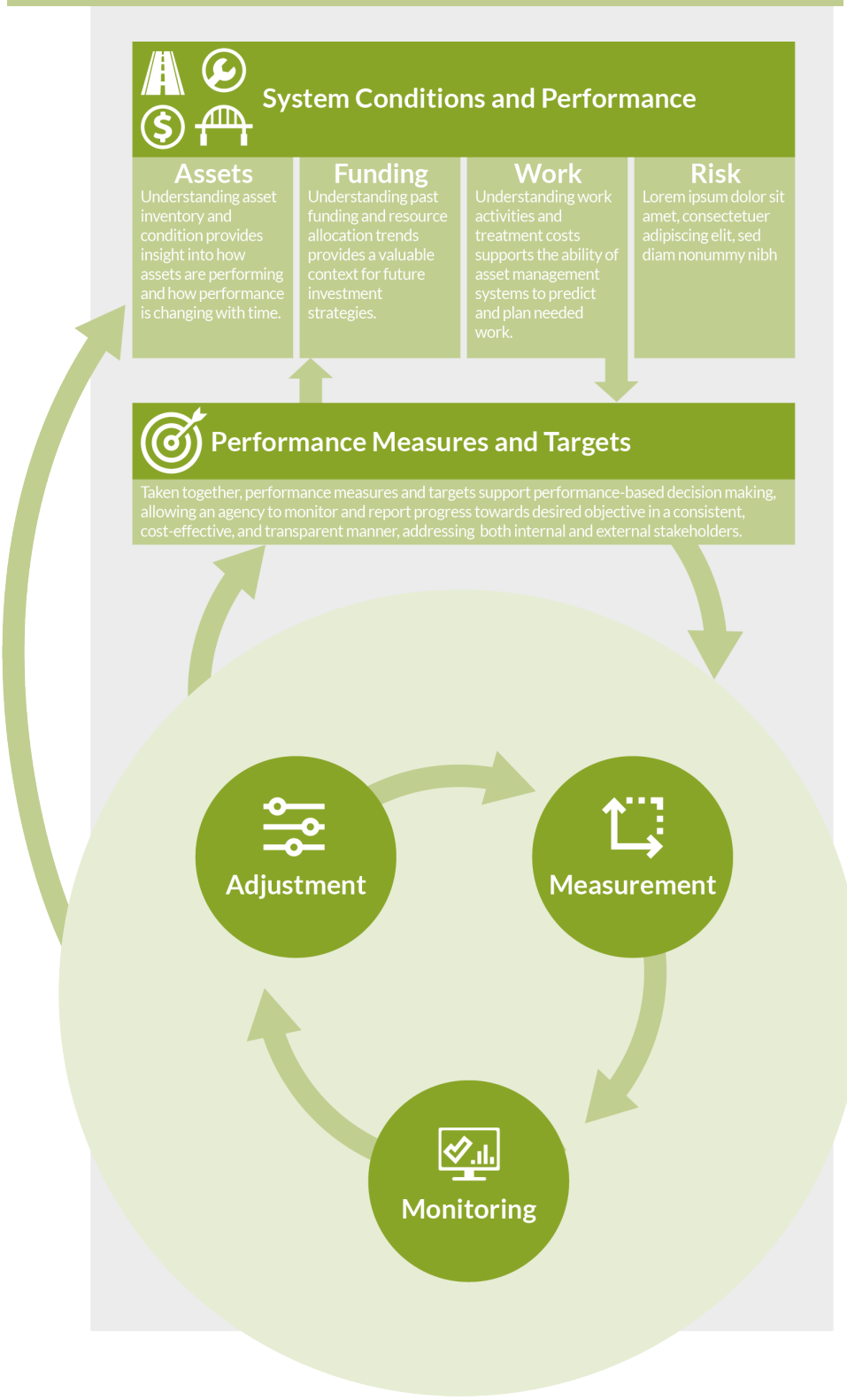
Arizona DOT's Link Between Strategic Objectives and Investment Decisions
Source: ADOT. 2014. Linking the Long-Range Plan and Construction Program P2P Link Methodologies & Implementation Plan. https://azdot.gov/sites/default/files/2019/08/p2p-methodologies-implementation.pdf

The existence of a regular, ongoing processes to monitor and report results is critical to identifying and implementing improvements to system performance or to further the effectiveness of the performance management process. The continual monitoring and update of a performance management framework is reflected in Figure 6.1, which illustrates inputs to performance targets and how ongoing monitoring and adjustments are fed back into the framework to adjust future targets. The surveys conducted regularly to support a pavement, bridge or maintenance management system are examples of the types of performance monitoring activities fundamental to an effective performance management organization.

The 2008 AASHTO Primer on Performance-Based Highway Program Management identifies benefits to agencies with a performance management framework:

- Maintaining a clear and unified focus for making agency decisions based on agency priorities, public input and available resources.
- Using available funding more effectively to preserve or improve system performance while lowering life cycle costs.
- Allocating available resources based on analysis of past performance and expected conditions to address areas most in need of attention.
- Having the data to confidently defend funding requests or explain the impact of reduced budgets.
- Building a transparent and accountable organization by communicating the basis for making resource decisions.
- Meeting legislative requirements.

Figure 6.1 Monitoring and Adjustment in the TPM Process



TIP It is important to select performance measures that are meaningful to the agency and that can directly inform decisions. This may vary depending on the agency context, culture, and TAM maturity.

Performance Measures

Performance measures are used within a performance management framework to allocate resources and provide feedback on the effectiveness of the activities in achieving overall objectives. Performance measures are indicators used for evaluating strategies and tracking progress. A performance measure can be an indication of asset condition, such as a pavement condition rating, or an indication of an operational characteristic, such as the annual number of fatalities on a facility.

The most effective performance measures drive decisions that are important to the success of the program. For example, maintenance departments may use performance measures that track actual expenditures to planned expenditures to monitor annual work plan accomplishments quarterly and as part of Division Engineers' annual evaluations, as described in the North Carolina practice example.

It is also important that the measures drive the desired performance within an organization. For instance, a performance requirement that measures whether pavement or bridge designs are submitted on time might cause incomplete or incorrect submittals to meet a deadline, leading to an increase in construction modifications. A more effective measure might focus on a minimal number of design modifications during the construction phase of a project.

Effective performance measures should also primarily be outcome-based rather than output-based, meaning that they focus on the result or impact of an activity rather than the inputs that went into the activity. Several examples of outcome- and output-based measures are shown in the sidebar on Page 6-8. Outcome-based measures are generally preferred because they indicate the effect on the traveling public resulting from the actions taken, so they usually relate to user priorities such as the length of time for a road to be cleared after a snow event or the absence of litter and graffiti. They are developed based on a description of what an agency wants to achieve as a result of the actions undertaken. Outcome-based measures are commonly used for managing ancillary assets such as drainage assets and signs. For instance, the performance of drainage assets might be reported in terms of the percent of pipes/culverts greater than 50 percent filled or otherwise deficient and the performance of signs might be reported in terms of the percent of signs viewable at night.

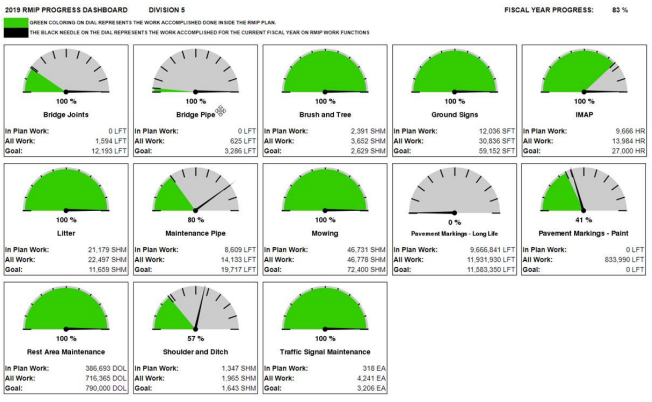
Output-based measures, on the other hand, track the resources used to achieve the outcome, such as the number of hours of labor used or the number of light-bulbs changed in a month. While the data is important information for managing resources, it does not necessarily drive outcomes that would matter to the public. For instance, travelers on a highway are much more interested in knowing when the road will be cleared of snow than how much overtime went into the operation.

Practice Example • Maintenance Performance Measures

North Carolina DOT

The North Carolina DOT authorizes its divisions to determine how funding will be used for maintenance activities and uses performance data to assist with this activity. Each year, Division Engineers submit annual plans detailing what work will be accomplished; these plans are reviewed quarterly with the Chief Engineer to discuss actual versus planned work. Their accomplishments are also displayed in a dashboard for internal use, as shown in the following image. Public-facing dashboards are also available showing overall conditions and performance trends. The Division Engineers are also held accountable for their performance, since their planned and actual performance data are incorporated into their annual evaluations.

Source: Leading Management Practices in Determining Funding Levels for Maintenance and Preservation. Scan Team Report, NCHRP Project 20-68A, Scan 14-01, National Cooperative Highway Research Program, May 2016.



When possible, agencies should use performance measures that are leading measures rather than lagging measures to influence future decisions. A leading measure uses changes in performance to provide insights into potential changes that might influence a future decision one way or another. For example, knowledge that a ramp meter has exceeded the manufacturer's suggested service life might drive a decision to replace that meter. Similarly, increases in equipment downtime might indicate risks due to an aging fleet are growing or that planned operational activities will not be performed as planned. A lagging measure, on the other hand, looks back on the results of past investment strategies after the decisions have been made. Because a lagging measure is recorded after the fact, there is a delay (lag) in the agency's ability to adjust its practices and improve performance. Bridge and pavement condition measures are examples of lagging measures because the reported conditions reflect the impact of decisions made several years in the past. Lagging measures are commonly used to evaluate a program's effectiveness or to verify that actual investments achieved projected results.

In transportation, an agency might have a lagging measure for tracking complaints responded to within a 48-hour window. The measure provides an indication of the public's satisfaction with the road network and is easy to monitor and report. However, if an agency really wants to effect change, it might develop leading measures to track the percent of complaints not worked on within a two-hour window or the percent of complaints that can't be resolved by the initial point of contact and must be passed to someone else. Focusing on these types of measures could drive agency decisions to ensure complaints are being worked on quickly and are being assigned to the right people. General characteristics of effective performance measures are presented in Table 6.1.

Use of Performance Measures

Performance measures are used to:

- Connect agency policies and objectives to investment decisions.
- Establish desired and targeted levels of service that consider past performance, current and future demand, stakeholder priorities, and anticipated funding.
- Align agency policies, investments, and day-to-day practices in a meaningful and easily understood manner.
- Prioritize investment needs.
- Monitor and report progress towards desired objectives to both internal and external stakeholders in a consistent, cost-effective, and transparent manner as illustrated in practice examples from the Washington State, North Carolina, and Virginia DOTs.

Outcome- Versus Output-Based Performance Measures

Outcome-Based Measures

- Number of hours until clear pavement after a snow and ice event
- Grass height should not exceed 10 in.
- Percent of roads with no unsealed cracks greater than ½ inch wide

Output-Based Measures

- Number of hours of overtime required for a storm event
- Number of mowing cycles per season
- Amount of crack filling material used

Table 6.1. Desired Performance Measure Characteristics

Desired Characteristics	Rationale/Purpose
Measurable with available tools/data	May require no additional cost for data collection
Forecastable	Enables data-driven target setting based on future conditions
Clear to the public and lawmakers	Allows performance story-telling to customers and policymakers
Agency has influence over result	Measures agency activities rather than impact of external factors

Source: Federal Highway Administration,. 2017. *TPM Guidebook*.

TIP **Outcome-based measures better relate to performance characteristics noticed by the public and other stakeholders than output-based measures.**

	Funded level (MAP LOS target)	2015 results	2016 results	2017 results
Special Bridges and Ferry Operations[1]	A	A	A	A
Traffic Signal System Operations	C	B	C	B
Snow and Ice Control Operations	A	A	A	A
Bridge Cleaning	B	B	B	B
Urban Tunnel System Operations	B	B	B	N/A[2]
Regulatory/Warning Sign Maintenance	C	D	C	D
Intelligent Transportation Systems	A	A	B	A
Slope Repairs	A	B	A	B
Catch Basins and Inlets Maintenance	A	A	B	A
Barrier Maintenance	A	B	A	B
Pavement Striping Maintenance	B	A	B	A
Raised/Recessed Pavement Marking Maintenance	C	C	C	C
Vegetation Obstruction Control	C	C	A	C
Rest Area Operations	B	B	B	B
Sweeping and Cleaning	A	A	A	C
Highway Lighting Systems	A	B	B	C
Ditch Maintenance	B	B	A	B
Guidepost Maintenance	D	D	D	D
Stormwater Facility Maintenance	A	A	A	A
Culvert Maintenance	D	D	B	C
Pavement Marking Maintenance	D	D	C	F
Shoulder Maintenance	C	C	C	C
Noxious Weed Control	B	B	B	A
Guide Sign Maintenance	C	C	C	C
Nuisance Vegetation Control	D	C	D	C
Landscape Maintenance	D	D	C	C
Litter Pickup	D	D	D	D

Targeted and Actual Performance Results Used to Set Maintenance Priorities

Source: WSDOT. 2017. Multimodal Asset Performance Report. Washington State DOT. https://wsdot.wa.gov/publications/fulltext/graynotebook/Multimodal/AssetPerformanceReport_2017.pdf

Practice Example
Maintenance Accountability Process

Washington DOT

The Washington DOT uses its Maintenance Accountability Process (MAP) to comprehensively manage maintenance budgets and to communicate the impacts of policy and budget to both internal and external stakeholders. Field condition surveys are conducted annually to assess the condition of 14 assets on the highway system such as signs and signals, ITS assets, tunnels, and highway lighting. For each asset, a level of service target is established, based on expected funding levels and importance of the asset to the agency's strategic objectives. The targeted and actual performance is summarized on a statewide basis and presented to the legislature, media, internal stakeholders, and other DOTs in a format similar to what is shown in the figure (https://www.wsdot.wa.gov/NR/rdonlyres/8EC689DF-9894-43A8-AA0F-92F49AC374F5/0/MAPservicelevelreport.pdf). In 2018, Washington State DOT achieved 77 percent of its highway maintenance targets. Targets that were not achieved are shown as red bullseyes and areas where the targets were exceeded include a checkmark with the bullseye. The results illustrate where additional investment is needed on a statewide basis and provides a basis for setting maintenance priorities during the year.

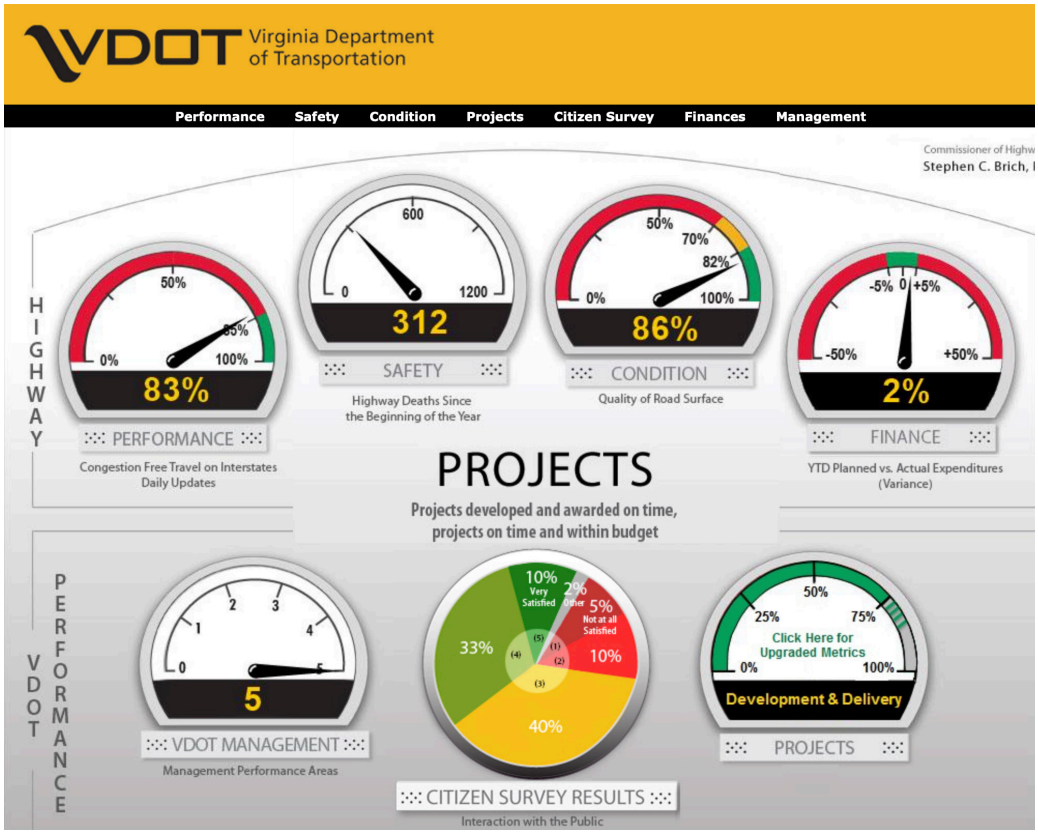
The Gray Notebook and Gray Notebook Lite

Source: WSDOT. 2019. https://www.wsdot.wa.gov/Accountability/GrayNotebook/

Practice Examples
Performance Reports

Washington DOT

To support accountability, credibility, and transparency, the Washington State DOT publishes its quarterly performance report, referred to as The Gray Notebook. Each edition presents updates on multimodal systems' and programs' key functions and analysis of performance in strategic goal areas based on information reported to the Performance Management and Strategic Management offices of the Transportation Safety and Systems Analysis Division. Washington State DOT also publishes its Gray Notebook Lite, which highlights key metrics referenced in the Gray Notebook in a format for quick reading. Examples from each of these documents are presented in the figures.



Virginia DOT's Performance Dashboard

Source: Virginia DOT. 2019. http://dashboard.virginiadot.org/

Performance Dashboard

Virginia DOT

Performance dashboards are also a popular way to present progress, using color-coded indicators similar to those on the dash of an automobile. An example of the interactive dashboard available from the Virginia DOT is shown in the figure. The screen reports performance in seven areas (performance, safety, condition, finance, management, projects, and citizen survey results) and the needles indicate whether the performance is within targeted ranges. Hyperlinks are available in each area if a user wants to explore historical trends or explore performance objectives in more detail.

Future Directions in Performance Measures

As agencies advance the maturity of their practices and move towards investment decisions across assets and modes (as discussed in Chapter 5), there is increasing interest in the use of leading measures and asset performance measures other than asset condition.

Asset management plans document the processes and investment strategies developed by an agency to manage its infrastructure assets. These asset management plans support an agency's performance-based planning and programming processes for making long-term investment decisions and feed shorter-term project and treatment selection activities. Together, these activities ensure the investment decisions of an agency are aligned with performance objectives and goals.

Examples of these types of measures include:

- **Financial Measures –** Internationally, financial performance measures have been used successfully to express whether the level of investment has been adequate to offset the rate of asset deterioration or depreciation. For example, the Queensland Department of Infrastructure and Planning uses an Asset Sustainability Ratio defined as the capital expenditure

Practice Example
Performance Scorecard

North Carolina DOT

The North Carolina DOT has an interactive Organizational Performance Scorecard that provides an online indicator of the Department's success at meeting targets in the following six core goal areas:

- Make Transportation Safer.
- Provide Great Customer Service.
- Deliver and Maintain Infrastructure Effectively and Efficiently.
- Improve Reliability and Connectivity of Transportation Systems.
- Promote Economic Growth Through Better Use of Infrastructure.
- Make NCDOT a Great Place to Work.

An example of how the information is shown; it presents the target for an overall infrastructure health index and the most recent results. As shown by the red "x" in the box on the far right, NCDOT is not currently meeting its target of a health index of 80 percent or more.

Objective: Achieve an infrastructure health composite index of 80 percent or more

Performance measure: Combined infrastructure health score

PREVIOUS RESULT	CURRENT RESULT	TARGET MET
75%	74%	☒

North Carolina DOT's Organizational Performance Scorecard Website – Excerpt

Source: NCDOT. 2019. https://www.ncdot.gov/about-us/our-mission/Performance/Pages/default.aspx

being made on asset renewals (e.g., improvements) divided by the depreciation expense (discussed further in Chapter 4). If the ratio is less than 100 percent, the level of investment is not adequately replacing the depreciation occurring each year. Queensland also uses an Asset Consumption Ratio comparing the current value of the depreciable assets to their replacement value in order to show the aged condition of the assets.

- **Life Cycle Measures –** A life cycle performance measure is a relatively new leading measure, promoting the selection of sound, long-term strategies best able to maximize performance at the lowest possible cost. There are several life cycle performance measures under consideration by the FHWA, including the Remaining Service Interval (RSI), which is being validated under a research project. The RSI is based on identifying a structured sequence of the type and timing of various repair and replacement actions needed to achieve a desired LOS over a long timeframe at the minimum practicable cost. The results of the RSI evaluation may be used to generate a Life Cycle Impact Factor, summarizing the difference in life cycle costs associated with the various strategies being considered.
- **Sustainability Measures –** With an increased focus on identifying long-term sustainable solutions to transportation system needs, agencies may seek to develop new sustainability performance measures in order to properly indicate the impact a proposed solution may have on environmental conditions. The use of a recycling measure for gauging the amount of recycled material used in road construction is an example of this type of measure, as are measures for monitoring carbon dioxide emissions.

TIP **Making performance measures publicly available through reports, scorecards, or dashboards increases transparency into agency operations, which can serve as motivation to improve staff's desire to meet the standards established, thereby increasing the chance of success.**

Checklist

Characteristics of Strong Performance Measures for Managing the Condition of Ancillary Assets

In September 2018 a peer exchange was held in Nashville, TN, for maintenance personnel under NCHRP 20-44(05). A total of 45 practitioners representing 27 state DOTs, industry, and the Transportation Research Board (TRB) participated in the peer exchange. Based on the information discussed during the meeting, successful performance measures for managing infrastructure assets other than pavements and bridges should have most of the following characteristics.

- ☐ **They should be linked to agency policy objectives.**
- ☐ **As discussed in Chapter 4, they should be linked to the management approach selected for that asset.**
- ☐ **They should provide meaningful information that helps drive maintenance decisions related to investment priorities.**
- ☐ **They should link budgets and performance.**
- ☐ **They should clearly convey changes in impacts due to differing funding levels and investment strategies.**
- ☐ **They should link program decisions to project outcomes.**
- ☐ **They should be measured consistently, collected economically, and updated regularly.**
- ☐ **They should be part of an agency's routine business processes and supported by management systems or other analysis tools.**
- ☐ **They should provide managers with information needed to understand problems and suggest solutions.**

Examples for various ancillary assets included the following (from NCHRP Synthesis 470, *Maintenance Quality Assurance Field Inspection Practices*)

- ☐ **Drainage assets: Channel or culvert condition or flowline interruption.**
- ☐ **Roadside assets: Length of damaged or missing features, obstructions in the clear zone, grass height, volume of litter.**
- ☐ **Traffic assets: Damage, legibility or visibility, not performing as intended.**

Evaluating the Effectiveness of Performance Measures

Because of the important role performance measures have in supporting performance-based decisions, agencies should use care in selecting measures that drive the right types of results. This section introduces several approaches to evaluate the effectiveness of an agency's performance measures.

Assessment

In its handbook for agency executives[2], AASHTO suggests an assessment of performance measures should consider the following:

- **Is the number of performance numbers reasonable?** – An agency should retain performance measures addressing critical areas of importance that are maintainable with time. The Maryland and New Mexico DOTs have approximately 80 measures reviewed on a regular basis, but the Florida and Pennsylvania DOTs use approximately 15 to 20 measures to review strategic performance. Some agencies identify a small number (< 10) of KPIs selected from the pool of operational and tactical measures that best reflect an agency's progress toward achieving its overall goals.
- **Are the measures meaningful?** – Some agencies choose only to use easily measured performance activities because the information is easy to obtain. However, other measures may do a better job of driving good decision making.
- **Does the level of detail in data collection match the level of detail required to drive decisions?** – Agencies should balance data availability with the analytic rigor used to make decisions. For instance, if pavement markings are replaced every year, it is not necessary to collect retro-reflectivity infor-

2 AASHTO. 2003. *Strategic Performance Measures for State Departments of Transportation: A Handbook for CEOs and Executives.*

Practice Example
Evaluation of Performance Measures

Pennsylvania DOT

After using performance measures for years, the Pennsylvania DOT recognized that the number of measures being used had increased to a level that was difficult to manage. In 2011, the Pennsylvania DOT conducted an assessment of their performance measures using the following series of questions to guide their decisions as to which measures to keep, which to change, or which to delete:

- Who is using the measure?
- What exactly is being measured?
- Why is this particular measure needed?
- Whose performance is being measured?
- Is the performance goal defined?
- Does a similar measure already exist?
- Is the existing measure meeting the needs and intent or should it be modified?

If a measure was needed where no measure exists, the following additional questions were used:

- Does the measure affect continuous improvement?
- Is the data for the measure updated as frequently as needed? Should it be updated monthly, quarterly, or yearly?
- Is the measure easy to quantify?
- Is the measure easy to understand?
- Is it clear who owns the measure?
- Does the measure provide a means of comparison?
- Have unintended consequences been investigated?
- Can the unintended consequences be successfully mitigated?

The process has helped to ensure that the agency is focused on the right measures to drive desired results and behaviors. The analysis found several issues that could be addressed, including eliminating duplicate or overly complicated measures, modifying measures that were driving unintended consequences, and resolving data quality issues.

mation annually. Similarly, collecting data on one lane of a two-lane highway may be enough for approximating the condition across the full width of the roadway.

- **Do they support the right decisions?** – The performance measures should drive decisions in support of strategic objectives. For example, a performance measure based on the amount of overtime incurred after a snow event is less effective than one able to monitor the number of hours until the roads are cleared.
- **Are existing data sources reliable?** – In most situations, existing data can provide the information needed for performance management, but it must be reliable and maintained regularly to be useful.

An assessment of performance measures can be important, since many organizations find that over time, the number of performance measures they are managing can become unwieldy.

SMART Evaluation

As discussed earlier, performance measures are used to set desired or targeted levels of service. Targets may be short-term, such as the 2- and 4-year targets state DOTs are required to submit to FHWA, or they may be long-term targets, such as the desired State of Good Repair (SOGR) serving as the basis for an agency's TAMP.

Performance targets are evaluated using the "SMART" method, which evaluates whether targets are:

- **Specific**. The performance is explicitly described.
- **Measurable**. Progress towards the target can be monitored in a consistent manner.
- **Achievable**. The target considers past performance, expected changes in demand, available resources and other considerations that make it realistic.
- **Relevant** (also referenced as results-oriented). The target should be meaningful to the agency and drive the right outcomes.
- **Time-related** (also referenced as timely or time-bound). There is a stated timeframe for achieving the target.

Benchmarking

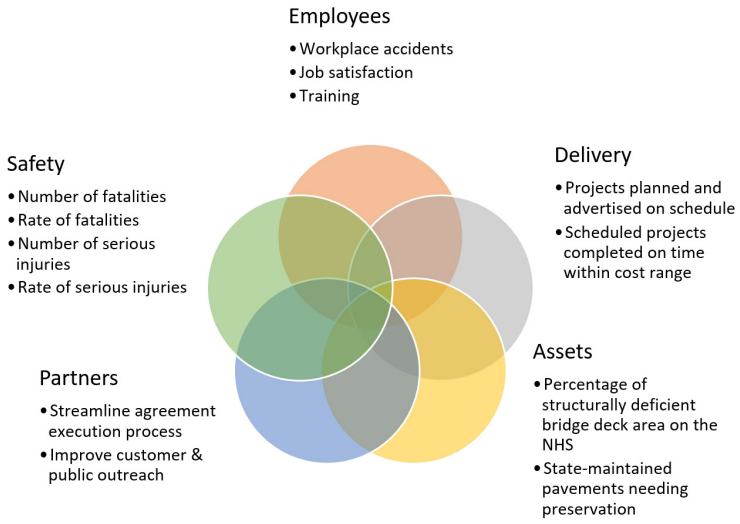
In simple terms, benchmarking is a process of comparing performance and practice among similar organizations as part of an agency's continuous improvement activities. Benchmarking provides an opportunity to learn about approaches used by high-performing organizations to uncover noteworthy practices, inform target-setting activities, or to foster innovation and improvement within an agency. Benchmarking should focus on improvement and lessons learned rather than as a way to penalize underperformers.

Practice Example • Performance Measure Evaluation

Nevada DOT

The Nevada DOT recognized that although performance measures were being reported regularly, they were not driving agency policies or decisions. The assessment evaluated the performance measures being used in each of the five key performance areas shown in the figure as well as the organizational culture to support performance management.

The study recommended improvements to emphasize the importance of messaging in order to advance the agency's performance management culture, extend the performance culture beyond the headquarters office to field staff, and develop job performance plans emphasizing accountability at the division, office and unit levels. The study also recommended the periodic review of performance measures to ensure their continued relevance to agency business processes.



Nevada DOT's five key performance areas and measures

Source: Nevada DOT. 2017. Adapting a Culture for Performance Management at the Nevada Department of Transportation.

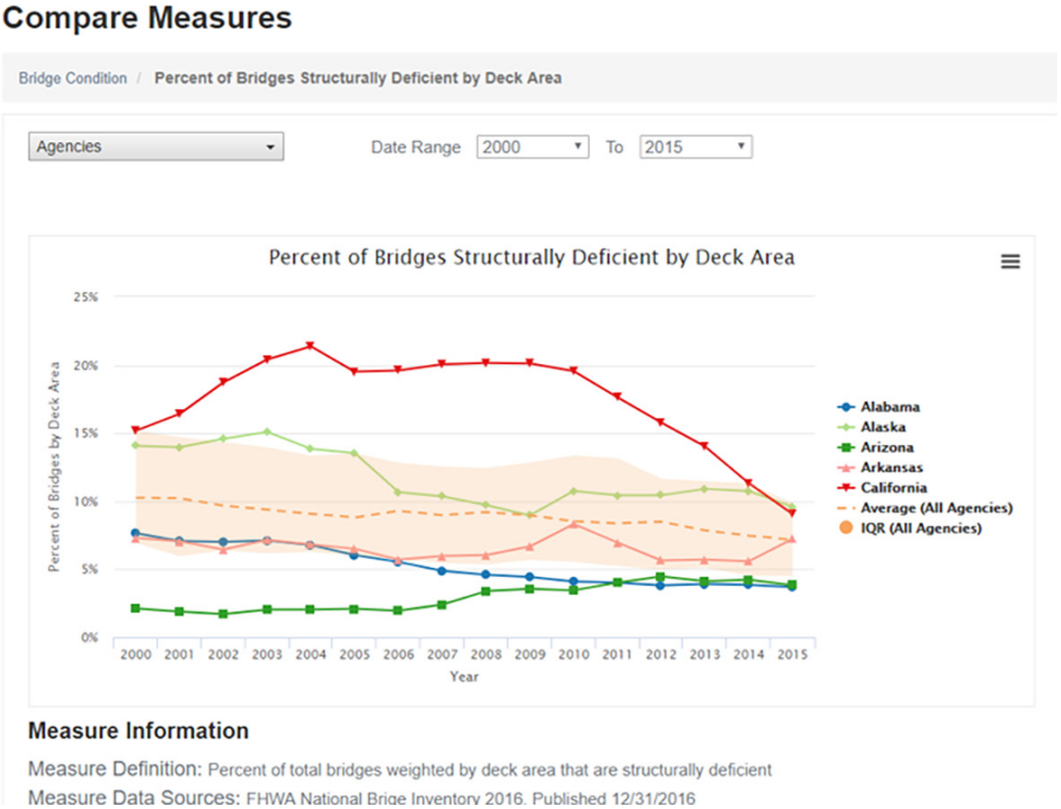
As mentioned in Chapter 1, AASHTO has developed a comparative benchmarking tool for enabling state DOTs to compare performance outcomes and practices with peer agencies as part of their continuous improvement activities (http://benchmarking.tpm-portal.com/). This includes a peer selection tool, so agencies can compare practices to peers with similar characteristics. It also features a performance comparison tool with a number of chart options enabling agencies to compare results. For instance, an agency may elect to compare pavement smoothness characteristics with a neighboring state. There is also a portal to facilitate the exchange of practices among registered DOT users through a Notable Practice Narrative.

An example from the AASHTO TPM Portal showing a comparison of bridge deck percentage determined to be structurally deficient is shown in Figure 6.2. Similar comparisons are available for safety, environmental, and non-motorized (bicycle and pedestrian) performance measures. For transit agencies, Transit Cooperative Research Program (TCRP) Report 141, *A Methodology for Performance Measurement and Peer Comparison in the Public Transportation Agency*, provides specific guidance for comparing performance with other agencies.

Audits

Internationally, ISO standards include the conduct of periodic internal audits to help an agency evaluate whether its asset management program and components meet the agency's needs, adhere to best practices and are being used to support decisions. In addition, agencies use auditing for service providers to confirm contract compliance in situations where road network maintenance and management activities have been outsourced.

Figure 6.2 Example Performance Comparison from the AASHTO TPM Portal



Source: TPM Portal. 2019. http://benchmarking.tpm-portal.com/compare/bridge-condition/deficient-bridges

Are These Smart Targets?

100% of the bridge designs are submitted on time during the fiscal year

Although this target is specific, measurable, achievable, and time-related, it may not be considered relevant because it does not necessarily promote completed, accurate designs to be submitted–only that they be submitted on time. A better target might reference designs not leading to revisions during construction.

Respond to public complaints on a timely basis

This target is not specific, since it does not clearly define what is meant by a timely basis. It could be improved by referencing the number of times a complaint is touched before it is resolved successfully or the agency could specify the period of time for resolving a complaint.

Reduce the percent of reduced load-rated bridge decks by 5% in 5 years

This target passes the SMART test, assuming that resources are allocated to achieve this goal.

How-to

Benchmark Performance

To benchmark practices with other state DOTs, agencies can use the steps below. These steps are provided in more detail in NCHRP Report 902 *Benchmarking and Comparative Measurement for Effective Performance Management*.

1. Set the stage

Identify a performance area to benchmark, assemble the team, select a leader, establish objectives and ground rules, and build agency support for the process.

2. Select peer agencies

Select peer agencies with similar characteristics, such as location, size, system and service characteristics, and traffic demand.

3. Define the approach

Choose and define one or more measures to compare.

4. Obtain data

Gather the data needed from peer agencies, national databases, or other sources.

5. Analyze data

Evaluate the quality of the data and address missing or incomplete data, data that does not fall within the valid range, or other data problems.

6. Identify noteworthy practices

Contact top-performing agencies to discuss key elements that influenced their success.

7. Communicate results

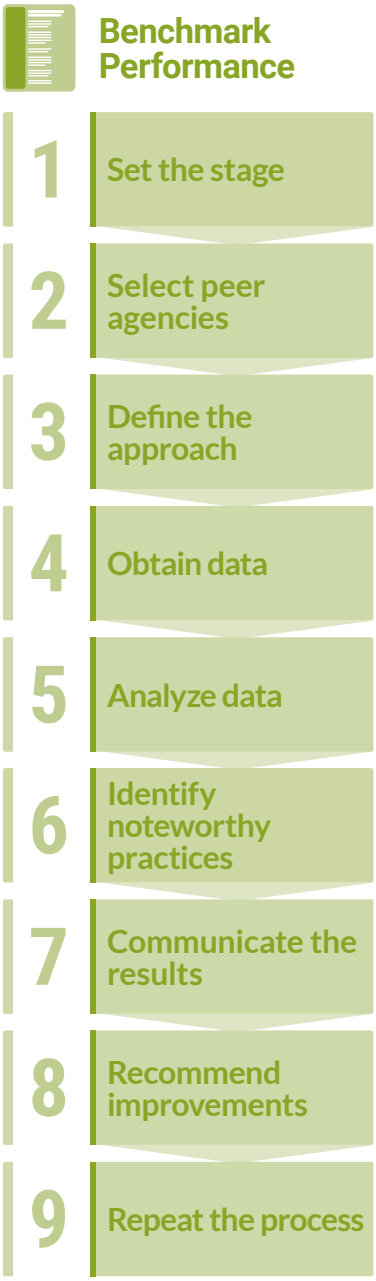
Share the findings with agency leadership, impacted staff, and/or other stakeholders.

8. Recommend improvements

Determine what steps could be taken to improve performance.

9. Repeat the process

Consider benchmarking as an important steps of continuous improvement within the agency.



TIP The AASHTO TPM Benchmarking Tool (http://benchmarking.tpm-portal.com/) was designed to assist state DOTs with benchmarking TPM data, providing a data source and comparison tools.

Section 6.2

Monitoring the State of Assets

Performance-based decision making depends on the availability of reliable and consistent data. For asset management decisions, asset inventory and condition information is most commonly used; however, other performance characteristics may also be used to monitor performance. This section introduces the types of inventory and condition information commonly used to support asset management decisions and describes strategies for keeping the data current. This section does not describe the methods used to collect inventory and condition information. That information is provided in Chapter 7.

This section has two parts:

1. **Types of Performance-Based Data to Monitor.** This part describes the use of inventory and condition information as the most common data used to monitor asset performance.
2. **Maintaining Asset Data.** This part introduces methods to keep asset performance data current.

Types of Performance-Based Data to Monitor

This section describes the types of information that should be collected and maintained to support performance-based decisions for physical assets. This section focuses on asset inventory and condition information for life cycle management, but recognizes that other operational performance characteristics may be important to determine whether an asset is fulfilling its intended function.

Differences in Performance and Condition

The terms 'performance' and 'condition' are often used interchangeably, although they have different meanings in a performance-based environment. The performance of an asset relates to its 'ability to provide the required level of service to customers[3]' while condition is generally considered to mean the observed physical state of an asset, whether or not it impacts its performance. For example, a bridge with scour may continue to perform adequately in the short-term even though it may receive a low National Bridge Inventory (NBI) rating because of the deterioration.

Inventory Information

An asset inventory provides information other than performance data important for estimating the amount of work needed, identifying the location of work in the field and determining characteristics capable of influencing the type of work to be performed. The RCM approach introduced in Chapter 4 can be used to help an agency determine what information is needed to support the management of each type of asset. The asset inventory requirements for those assets managed based on a specified interval for repair, such as pavement markings, is very different than those required for an asset managed using a condition-based approach, such as pavements or bridges. Regardless of how detailed the asset inventory is, it is important an agency establish processes to ensure data quality and keep the inventory current over time.

There are several basic data attributes essential to effectively managing transportation assets, including asset type, quantity and location. Additional information that is important is to differentiate between the types of work to be performed, which may also be added to the inventory, the type of material used to construct the asset, the last time work was performed and factors influencing the use of the asset (e.g. traffic levels, highway functional classification or climatic conditions).

As discussed in Chapter 7, managing asset inventory information using an integrated approach to data management helps promote consistency in asset data across an agency and provides access to help ensure the data is used by decision makers at all levels of the organization. An out-of-date inventory makes it difficult for an agency to estimate work quantities accurately for budgeting purposes.

3 IIMM, Version 3.0, 2006. Page 3.39

Condition Information

Asset condition information is used to determine how assets are performing and how performance changes over time. The lack of condition information may lead to premature or unexpected failures with the potential to be very costly, negatively impacting system performance and increasing agency risks. Methods of collecting asset condition information are discussed further in Chapter 7. To ensure that condition information remains current, it is important that the information is updated on a regular basis.

Asset Condition

There are several approaches for assessing asset conditions, each of which is influenced by the type of asset and the resources available to support the process. Typically, an assessment of asset condition involves a method of evaluating the presence of deficiencies and/or deterioration at the time of inspection. The results are used to assign a rating or LOS used to determine the need for maintenance, rehabilitation or replacement now or in the future. Asset condition ratings may also be used to establish rates of deterioration, allowing an agency to forecast future conditions for planning purposes.

Examples of commonly used types of asset condition ratings are listed below.

- A pavement condition index based on the type, amount and severity of distress present, which could be on a 0 to 100 scale, with 100 representing an excellent pavement.
- The National Bridge Inventory (NBI), which assigns a rating between 1 and 9 based on the deterioration present in each element (deck, superstructure, substructure and culvert).
- A LOS rating of A to F for maintenance assets, such as the percent blockage in a culvert or the percent of guardrail not functioning as intended.

Maintaining asset condition information is important for evaluating performance to determine whether improvements are needed to achieve the agency's strategic objectives. The lack of current condition information, or a lack of confidence in the condition information, makes it difficult to present investment needs to stakeholders with any degree of confidence.

Asset Performance

The results of condition surveys or inspections are used to evaluate the performance of each asset in terms generally understood by stakeholders, such as Good, Fair or Poor.

It is common for transportation agencies to report the percent of the network in Good or Fair condition or the percent of drivers traveling on roads in Good and Fair condition. Asset performance can also be reported in terms of a health index, such as the Remaining Service Life (RSL) used by some state DOTs to indicate the amount of serviceable life left in the asset. In the maintenance community, some state DOTs have developed a Maintenance Health Index or overall LOS grade to represent the performance of the entire Maintenance Division rather than report the grades of each category of assets separately.

Asset performance also influences overall system performance, as demonstrated by the impact on system reliability associated with unplanned road or bridge closures due to flooding or an on-going lack of maintenance. Performance data related to delay, unplanned closure frequency, GHG emissions, and crash locations may all be impacted by asset conditions and affect an agency's ability to achieve its broader, strategic performance objectives such as system reliability, congestion reduction, environmental sustainability, and freight and economic vitality. For example, it is important to monitor performance characteristics such as travel time reliability to determine whether capital improvements are needed to add additional lanes or whether ITS assets could improve traffic flow during peak periods.

Practice Example
Asset Condition and Performance Information Mapping System

Ohio DOT

The Ohio DOT recognizes the importance of integrated management systems to support both life cycle and comprehensive work planning activities. One of the tools developed by the Ohio DOT is its Transportation Information Mapping System (TIMS), which enables planners, engineers and executives to access and manage key asset, safety and operational data in an integrated web-mapping portal (https://gis.dot.state.oh.us/tims). The portal is available to both internal and external stakeholders and allows users to access information about the transportation system, create maps or share information. The data integration efforts enabling TIMS are now underpinning all management system implementations.

Maintaining Asset Data

This section describes several approaches to keeping asset inventory and condition information current, so it can be used reliably to track accomplishments and evaluate current and future needs. The methodologies used to collect the asset information is discussed in Chapter 7.

Maintaining Inventory Information

One of the challenges transportation agencies face is keeping their asset inventory current, because it can require business processes dependent on individuals or agency work areas that differ from the primary asset owners. For example, construction may be responsible for installing new guardrails as part of a pavement-resurfacing project, but the information is not always made available to the maintenance division responsible for budgeting and scheduling guardrail repairs.

Establishing Processes to Update Inventory Information

Some types of inventory information change regularly while other information changes infrequently. As a result, it is important to classify each type of data and establish procedures in order to ensure the inventory is updated as information changes. An agency should establish business processes to ensure any changes to the inventory are reflected in relevant databases. For example, each time a pavement improvement project is completed, the database should be updated with information about the new surface type, the project completion data and the other assets replaced as part of the project. Establishing these processes and holding individuals responsible for updating this information are important for the ongoing success of a performance-based management approach.

Maintaining Condition Information

Asset condition and performance information must also be updated on a regular cycle. In some cases, data collection cycles are mandated by regulations, such as federal requirements for reporting pavement and bridge condition information on the National Highway System. Where there are no requirements in place for condition reporting, the update frequency should be determined based on the resources available, how the asset is managed and the data analysis cycle. Different update frequencies may be established for different types of assets.

Asset condition information may be collected based on a regular interval schedule or an inspection may be triggered based on the asset's condition. For example, an asset in poor condition may require inspection more frequently than an asset in good condition. In general, asset information is updated on a 2- to 4-year cycle, but in some cases asset data is collected more frequently. For instance, some agencies collect performance data on maintenance assets several times a year to ensure they are in good working order and performing as expected. The condition of other assets with a slower rate of deterioration may be conducted less frequently.

Practice Example
Defining Roles & Responsibilities To Ensure Data Stays Current

Virginia DOT – TAM Field Maintenance

The Virginia DOT maintains most of the assets on state roads and regularly assesses the condition of those assets for determining investment needs. For pavements and bridges, there are asset leads at both the central office and in the districts to monitor conditions and update the database based on work completed. Asset leads at the central office manage statewide data monitoring and analysis and provide guidance on the work that is needed. The asset leads in the districts are responsible for implementing the work and recording completed work in the bridge and pavement management systems so the information is always current.

Section 6.3

Monitoring Funding and Resource Allocation Trends

Understanding past funding and resource allocation trends provides valuable context for future investment strategies. This section discusses the types of trends commonly used in TAM and illustrates how the trends can be used to adjust a program.

This section has two parts:

1. **Types of Funding and Resource Trends.** This part introduces the types of funding and resource trends that can provided useful information for making investment decisions.
2. **Using Trend Data to Make Program Adjustments.** This part describes and illustrates how funding and resource allocation trends can be used to improve decisions.

Types of Funding and Resource Allocation Trends

This section describes several funding and resource allocation trends that are commonly used by the transportation industry.

Funding and Resource Allocation Trends

Historical trends related to the performance and condition of the highway system or the way investments have been made provide useful information for estimating future investment needs. These trends contain important insights into future needs and highlight the consequences associated with different tradeoffs in the various use of funds. This information can be useful in developing the life cycle management and financial planning portions of a TAMP.

The FHWA report *Financial Planning for Transportation Asset Management* introduces the importance of historical trends for the following reasons:

- Illustrating whether past expenditures were adequate or whether they need to increase
- Helping an agency shift from a budgeting process based on incremental growth in expenditures to a performance-based approach addressing need
- Building agency confidence in forecasting future investment needs and conditions

Types of funding and resource allocation trends commonly include:

- Revenue trends over time by funding source
- Funding allocations by program category over time
- Expenditures by asset and work category over time
- Expenditures by system (e.g., Interstate, non-Interstate NHS and non-NHS) over time
- Expenditures by district or region over time

Revenue Trends by Funding Source

A summary of revenue trends by funding source provides an agency with a foundation for projecting the amount of revenue available in future years to address asset needs. These trends help an agency understand whether revenues are increasing or decreasing, identify which revenue sources have significant amounts of variability or more consistent growth rates over time, and illustrate whether the agency is relying on unsustainable funding. The information is a vital foundation for forecasting future revenue levels for planning purposes and helping formulate the assumptions upon which future revenue forecasts are based.

An example of a revenue trend table is provided in Figure 6.3. The trends illustrate which revenue sources have increased or decreased over time and are thus important for making future revenue projections. The table also highlights how overall funding levels peaked between 2007 and 2009 largely due to state bonds in 2007, federal bonds in 2007 and 2009 and one-time ARRA (American Recovery and Reinvestment Act) funding in 2009. When these three funding sources ended, the available revenue reverted to 2005 levels. If the effects of inflation were taken into consideration, the agency could also show how the purchasing power of available funding has dropped in later years.

Funding Allocations by Program Category

Transportation agencies typically track funding allocations and expenditures by program category, but the number of categories and the category descriptions may vary depending on the agency. In general, funding allocations are tracked separately for the highest-value assets and the performance of these assets are incorporated into the agency's strategic goals. This may lead agencies to track investments made in pavements, bridges, maintenance, safety and other assets. Within each of these categories, agencies can project the level of funding expected and predict the conditions and performance expected for it. Past trends in funding allocations by category can help indicate whether expected funding will be adequate to achieve the stated objectives.

Expenditures by Asset and Work Category

Information on past expenditures by asset and work type, along with resulting conditions, provides insight into the amount of funds needed for these activities in future years or helps set expectations for conditions achievable in future years. Where there are differences in planned expenditures and needed expenditures, the agency may report the existing financial gap.

Expenditures by System

Expenditures by system also provide valuable information, laying the groundwork for predicting how future funding levels will impact the condition of the Interstate, non-Interstate NHS and non-NHS assets. The information by system also conveys the agency's past priorities for system investment, with higher levels of investment in high-volume facilities being common.

Expenditures by District or Region

Trends showing expenditures by district or region may be used to identify geographical areas requiring more focus on a particular type of work or experiencing an accelerated rate of asset deterioration. Information provided at this level can also be used to identify differences in production rates with the potential to serve as the basis for improving future practices. For example, a district with an unusually high production rate for repairing guardrail end treatments could share its experiences with other districts to improve the overall productivity rate at the statewide level.

Figure 6.3 Example of historical revenue trends by funding source

Sources	2003	2005	2007	2009	2011	2013	2015
State Motor Fuel Tax	$658	$651	$644	$637	$630	$624	$617
License, Vehicle Fees	$60	$60	$59	$57	$53	$50	$50
Other	$21	$21	$23	$22	$21	$22	$22
State Bonds	$20	$76	$296	$92	$0	$0	$0
Federal-aid	$725	$789	$825	$857	$900	$888	$877
ARRA	$0	$0	$0	$273	$10	$0	$0
Federal Bonds	$0	$0	$120	$80	$0	$0	$0
Total Revenue	$1,484	$1,597	$1,967	$2,018	$1,614	$1,584	$1,566

Source: NHI 136002 – Financial Planning for Transportation Asset Management. Participant Workbook.

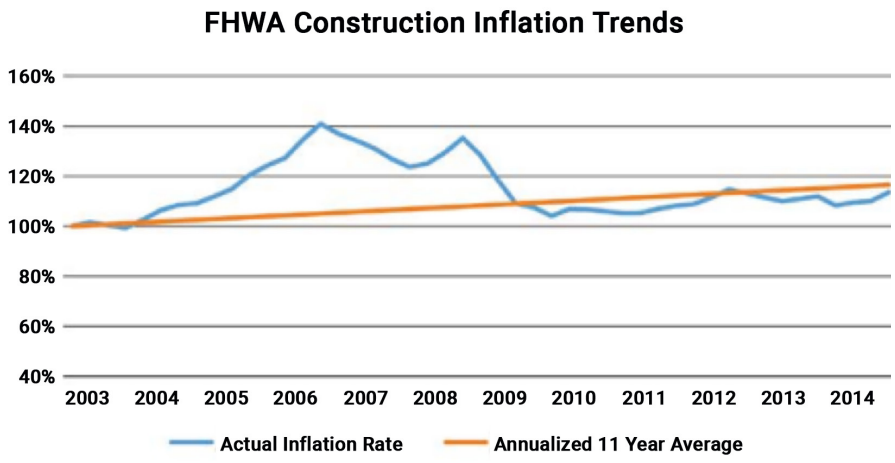
Overcoming Challenges Associated With Trend Analysis

It can be difficult to predict future trends based on historical data, especially when there is a significant amount of variability occurring. For example, the FHWA construction inflation trends shown in Figure 6.4 illustrate how variability can have a significant impact on historical trends. In this example, the FHWA National Highway Construction Cost Index has a compound annual growth rate of 1.16 percent between 2003 and 2014. However, between 2005 and 2008, significant inflation occurred. An agency preparing a construction estimate in 2006 would look very different than one developed in 2003 or 2013. To address this type of challenge, the agency can include any assumptions made, when preparing an estimate based on trends with significant variability. It could also conduct a sensitivity analysis to better understand the consequences of the potential variability.

Another challenge in using trends is the fact that past performance does not guarantee future results, especially if there have been changes in the condition impacting performance. For example, a bridge may have performed well for years, but changes in traffic volumes and weights could significantly increase the rate at which the bridge deteriorates. Similarly, the use of new bridge deck materials may last longer than the materials used previously. To address these challenges, an agency may find it beneficial to modify historical models to better reflect current and future conditions. Monitoring performance over time will allow the agency to develop new models specific to changes in traffic or materials.

A third challenge arises in trying to develop trends for expenditures in work activities when there are inconsistencies within the agency as to what treatments are included in each category. This typically occurs with work activities related to maintenance and preservation. For example, the categorization of a treatment may vary depending on whether the work was performed by inhouse forces or a contractor. Another example is when a preservation treatment is used as a stop-gap improvement on a project that needs more substantial repairs. Again, the actual performance of the stop-gap improvement could be much shorter than the application of that same treatment when used as a preservation improvement. The absence of standardized work categories or the use of stop-gap treatments consistently across the agency can make it difficult to show meaningful performance trends for these types of activities. As a result, it can be difficult to show the benefits associated with these treatments. The solution is to define treatments consistently throughout the agency and to ensure that the treatments are being used as expected.

Figure 6.4 Actual and compound average annual construction inflation trends Between 2003 and 2014



Source: FHWA. 2015. *Managing Risks and Using Metrics in Transportation Asset Management Financial Plans.* .

Using Trend Data to Make Program Adjustments

This section illustrates how some agencies have successfully used historical trends to make program adjustments.

Adjusting a Program Based on Trends

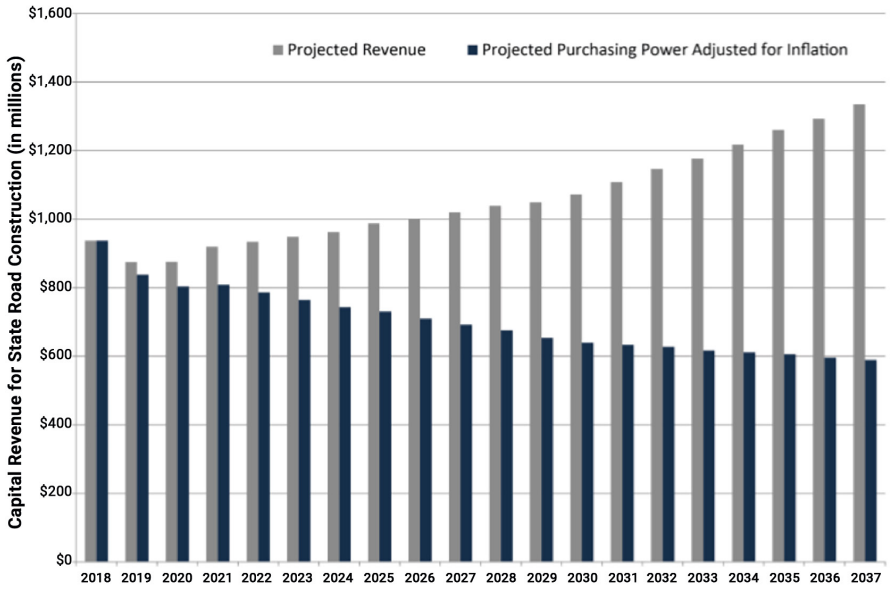
The availability of historical trends is integral for making future projections as part of the planning and programming process. As shown by the examples included in this section, agencies have used trend data creatively to make program adjustments and more effectively align planned investments with strategic objectives.

Practice Example

Impact of Inflation on Road Construction Expenditures

Minnesota DOT

The Minnesota State Highway Investment Plan (MnSHIP) outlines a 20-year strategy for investing in the state highway system. The most recent document, published in 2017, outlines investment priorities for the period from 2018 to 2037 (http://minnesotago.org/application/files/3414/8431/5979/ MnSHIP_Final_Jan2017.pdf). One of the figures included in the plan uses historical inflation trends to illustrate the declining purchasing power of revenue due to construction costs growing at an annual rate of approximately 4.5 percent. This cost growth rate exceeds the projected annual revenue growth rate of approximately 2 percent, which is expected to erode over half of the buying power of revenues by 2037. As a result of this analysis, MnDOT was able to communicate its financial situation with stakeholders and could better manage the risks associated with continued construction cost increases over the planning period.



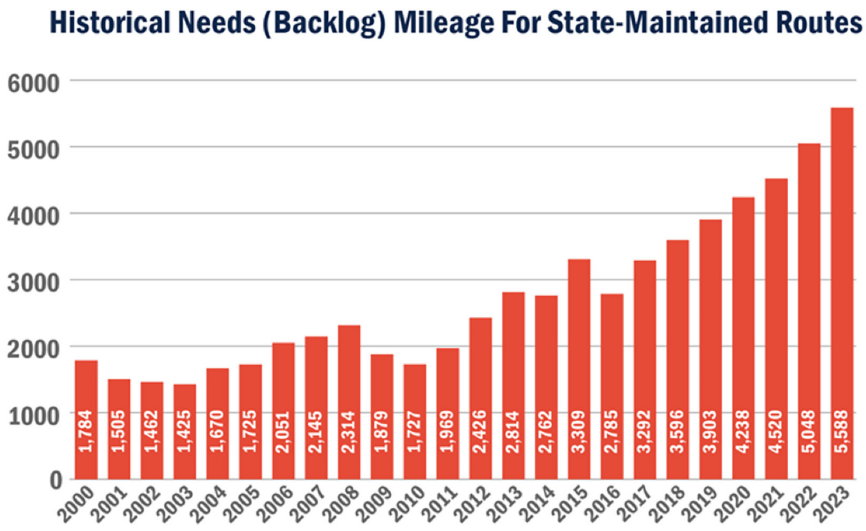
Anticipated construction revenue by year including adjustments for inflation.
Source: Minnesota DOT. *20-Year State Highway Investment Plan 2018-2037.*

Practice Example

Impact of Inflation on Road Funding

Illinois DOT

The Illinois DOT used a graph showing the number of miles of state-maintained roads in need of unfunded rehabilitation or reconstruction, which was referred to as the backlog. The graph, shown in the figure to the right, illustrates the fact that the backlog was growing over time due to the inadequacy of funding. The increasing trend in backlog prompted the Illinois DOT to reconsider its approach to selecting projects and treatments, moving towards the increased use of preservation treatments to slow the rate at which pavement conditions drop into a backlog condition. In addition to the change in treatments, the Illinois DOT developed a new pavement performance measure based on the percent of the network in good enough condition to be a candidate for a preservation treatment. The change in performance measure was intended to shift funding priorities from deteriorated pavements to those that could be kept in good condition for a longer period of time. The changes were documented in the Illinois DOT's April 2018 Transportation Asset Management Plan (http://www.idot.illinois.gov/transportation-system/transportation-management/planning/tamp) and were used in developing the fiscal year 2019-2024 Multi-Year Proposed Highway Improvement Program. In addition, new software tools are being acquired to further support this improved approach to managing pavements and bridge assets.



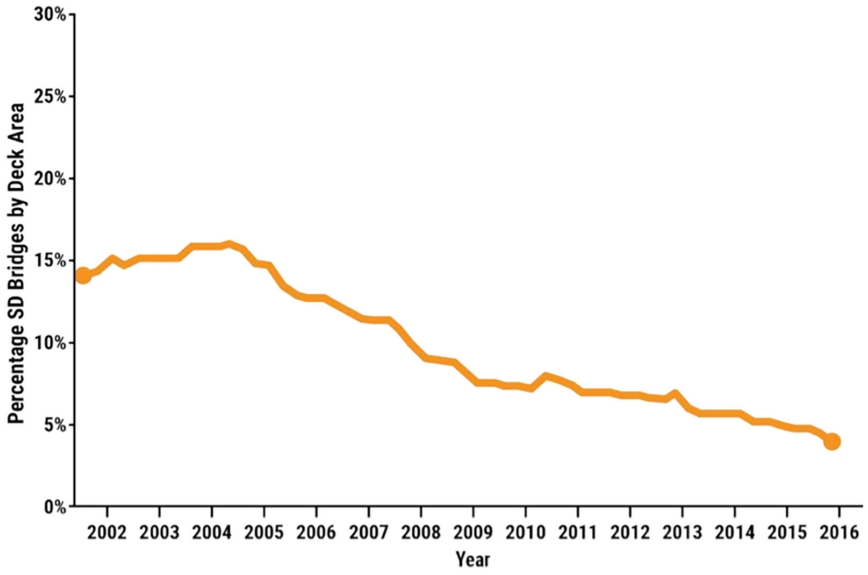
Historical pavement backlog trend.
Source: Illinois DOT Transportation Asset Management Plan. 2018.

Practice Example

Using Condition Trends to Illustrate the Effectiveness of Past Investments

New Mexico DOT

In 2004, the New Mexico DOT realized that a significant percentage of state-maintained bridges were classified as structurally deficient. To address this issue, the agency targeted increased investments in bridge preservation. Going forward, the agency funded rehabilitation activities for bridges in poor condition and added preventive maintenance activities for bridges in good or fair condition to slow the rate of deterioration on these bridges. As shown in the figure to the right, the program has been very effective in improving bridge conditions. Adding a line to the graph showing the targeted conditions would help convey the impact that the increased preservation expenditures have had on achieving performance objectives.



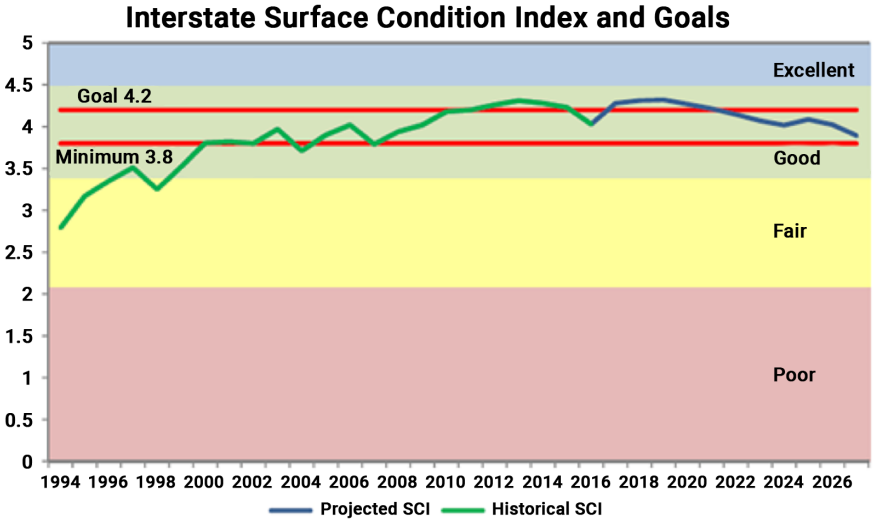
Trend showing the decrease in structurally deficient bridge deck area resulting from targeted investments.
Source: New Mexico DOT Transportation Asset Management Plan. 2018

Practice Example

Using Historical and Projected Conditions to Evaluate Performance Targets

South Dakota DOT

To determine the effectiveness of road investments, the South Dakota DOT uses historical trends and projects conditions for each road category to show whether targeted conditions can be achieved with planned investment scenarios. The figure to the right illustrates the type of graph developed for the Interstate network. As shown, the graph presents both historical and projected conditions based on a Surface Condition Index (SCI) that ranges from 0 to 5, with 5 representing a distress free pavement. Overlaid on the graph is the acceptable condition range, which in this case spans an SCI between 3.8 and 4.2. The graph shows that Interstate conditions gradually improved over time. Although it projects average future conditions to drop, they are expected to continue to fall into the acceptable condition range. The results of the analysis provide the agency with confidence that the planned investments will achieve the desired condition levels over the analysis period. In addition, the projections are updated annually to provide a picture of changing financial trends and funding availability. This allows the DOT to react to any downturn in the projections.



Past and future pavement conditions and goals.
Source: South Dakota DOT Transportation Asset Management Plan. 2019. https://dot.sd.gov/media/documents/SDDOT2019TAMPFHWASubmittalrevised8-28-2019.pdf

Section 6.4

Monitoring Asset Work and Costs

As discussed previously in Chapter 2, in order to reliably assess current and future work needs over an asset's life cycle, it is important to ensure completed maintenance and capital work activities are tracked and incorporated into the asset management programs. This section establishes the importance of tracking work history information, presents approaches to track the information and illustrates how work history information can be used to update and improve performance predictions.

This section has three parts:

1. **Importance of Tracking Work Histories and Treatment Costs.** This part establishes the importance of keeping information about work conducted on an asset current.
2. **Establishing Business Processes to Support Work History and Cost Tracking.** This part describes the processes that help ensure that work history and cost information are kept current.
3. **Using Work History Information to Improve Models.** This last part illustrates how work history information can be used to improve models used to support investment decisions.

Importance of Tracking Work Activities and Treatment Costs

This section describes the factors that should be considered for keeping a management system current.

Why It Is Important to Track Work Activities and Treatment Costs

Asset management systems, such as pavement and bridge management tools, rely on the availability of complete, up-to-date inventory information to serve as the basis for all system recommendations. At a minimum, the most recent work activity and completion date are necessary for establishing an asset's age or the length of time since work was last performed. These factors are key to setting a maintenance service interval or predicting the need for future work. Treatment cost information is used to estimate the cost of recommended work activities, so realistic numbers are important for planning and budgeting.

Work Activities

The level of detail required to track work histories is largely dependent on the sophistication and maturity of the asset management program. It is important to have access to information indicating when the asset was installed or constructed, or when the most recent major work activities were performed. Additional information about maintenance activities performed to preserve or improve the asset is beneficial if it can be provided efficiently and incorporated into decisions about managing an asset over its life cycle.

An agency should incorporate completed work activities into a management system at least annually, at the end of each construction season. At a minimum, the asset management database should be updated to reflect any changes to the asset properties, such as a change from a concrete to an asphalt pavement, and the date when the change was made.

Treatment Costs

Including the cost of maintenance and rehabilitation activities in a computerized maintenance system provides a historical record of how treatment costs have changed over time. The information from the management system, as well as bid documents, can be used to establish unit costs for each type of work activity possibly recommended by the system. Unit prices for each work activity included in the system are needed.

For many transportation projects, improving the condition of the asset is only one part of the total cost of a project. There are many other costs to incorporate into the unit price when estimating the cost of a treatment recommendation, including the cost of pavement markings, guardrails and signs on a pavement project. If these costs are ignored, the cost of a project will be underestimated, and an agency may program more work than can be constructed over a given timeframe. Some agencies inflate treatment costs by a factor of 30 to 40 percent to ensure the costs associated with project

design and the improvement of ancillary assets are considered in the unit cost for a given treatment. Using this approach, $0.30 to $0.40 is added to every dollar associated with the cost of the work itself. The inflated cost (e.g., $1.40) is stored in the management system as the unit cost for estimating treatment costs.

Different unit costs may also be established to reflect different costs in urban and rural areas, or in different geographic regions of a state. These differences improve the accuracy of asset budgeting activities by reflecting the realities agencies face due to work activities in highly congested areas, differences in the availability of contractors and the scarcity of materials in certain areas.

In addition to being used to estimate budget needs, treatment cost information serves many other purposes. For instance, the cost of a proposed project and its expected life can be used to determine a Return on Investment to help ensure that the most cost-effective projects are being selected. The information can also be used to compare the effectiveness of one treatment over another, or one life cycle strategy over another. Cost information has also been used to demonstrate the benefits to using proactive maintenance across a transportation network rather than reactive maintenance.

Practice Example
Tracking Maintenance Activities

Montana, Tennessee, and Utah DOTs

Several state DOTs are employing the use of technology to track maintenance work activities as noted below.

When new assets are installed as part of a construction project for the Montana DOT, Construction personnel are required to provide Maintenance with the information needed for updating the asset inventory. Maintenance verifies the information provided by Construction before inputting it into the system.

The Tennessee DOT uses an automated data collection van to establish its asset inventory for approximately 20 assets. The inventory is entered into a maintenance management system at a summary level for each county and a "ghosting" technique is used to identify differences in the inventory from one year to the next year.

The Utah DOT extracts is asset inventory every two to three years from the LiDAR collected as part of the agency's annual pavement condition surveys; however, the DOT is moving towards a continuous inventory updating process that would be the responsibility of Maintenance supervisors.

Establishing Business Processes to Support Work History and Cost Tracking

To ensure that work history and treatment cost information is kept current, business processes should be established to maintain the data over time. This section stresses the importance of building business processes to update the data regularly.

Assign Responsibility

One of the first steps in establishing business processes to support the maintenance of work history and cost information is assigning responsibility to the appropriate person for managing the information. The individual assigned responsibility for updating work history and cost data in the management system is not always the individual responsible for providing the data. For example, some agencies assign responsibility for updating completed work history and treatment cost information to the maintenance or construction division, since they are typically involved in closing out a project. Regardless of who is assigned responsibility for the task, a clear line of accountability should be established as part of the business process.

Establish Processes to Update Work Activities

As discussed in Chapter 7, technology is improving agencies' ability to track completed work activities, so the information is available for use in an asset management system. The access to handheld data entry devices with map interfaces linked to a centralized database helps ensure all users of the information have immediate access to current and consistent information. Business processes reliant on field personnel to remember to provide information to another data user are generally not sustainable.

To help establish a reliable approach for keeping asset data current, an agency may consider developing a data and process flow map illustrating the flow and use of data across the agency. This type of document helps an agency better understand where the data comes from, where it is stored, who uses the information and what levels of access various users need. A data and process flow map may become part of an agency's data governance documentation in order to protect the integrity of asset data.

Build Buy-In To Support the Business Processes

Key to the success of any business process is establishing buy-in among the individuals responsible for each required step. This involves familiarizing the individuals with their responsibilities, providing tools and guidance for completing the activities efficiently and effectively and demonstrating how the information is used to support agency decisions.

Practice Example Inventory Update Requirements

Florida DOT

To ensure that the asset inventory remains current, the Florida DOT assigns district personnel responsibility for maintaining asset inventories and establishes guidance that no data in the inventory can be more than five years old. For new construction projects, it is required that the inventory be updated within 90 days of completion. The Florida DOT district offices develop a Quality Control (QC) plan and perform a QC check on the data at least once a year. The Florida DOT Central Office develops a Quality Assurance Review (QAR) plan and performs a QAR on the district's QC process and spot checks the data in the field. As a result of these requirements, the Florida DOT has a high degree of confidence in the numbers used for budgeting activities.

Using Work History Data to Improve Models

The availability of current work history and performance data allows agencies to develop and improve models used in a management system to predict future conditions and determine treatment effectiveness. This section describes and illustrates the use of this data to improve existing models.

Developing and Improving Asset Deterioration Models

An important function of an asset management system is the ability to predict asset deterioration rates so changes in condition over time can be modeled for use in planning and programming activities. In the absence of data, models can be developed based on expert judgment, but as historical performance trends are established based on actual data, the expert models should be replaced by or calibrated against the real data.

The AASHTO *Transportation Asset Management Guide: A Focus on Implementation (2011)* introduced the following thought process to help an agency evaluate their deterioration models and determine whether improved data is needed to enhance future forecasts:

- If there is disagreement with the timing for recommending a treatment, what is the difference? Does a difference of one to two years make a substantial difference to the program? This type of difference is typically the result of the program optimization models.
- If there is disagreement with the treatment, are the differences substantial, such as deck repairs versus bridge replacement? These differences are often the result of treatment rules but may indicate that deterioration rates are not correct. The deterioration model parameters may need to change (e.g., change traffic considerations or geographic location) or there may have been some work performed that the model is not aware of.
- If the differences are irreconcilable, the agency may decide to investigate the model setup and analysis further or may conduct research to see how other agencies have resolved similar issues.

Determining Treatment Effectiveness

The availability of work history and performance data also makes it possible to determine the effectiveness of different types of treatments over time. By adding cost information to an effectiveness analysis, an agency can determine the long-term cost-effectiveness of different treatment strategies.

Practice Example
Evaluating the Effectiveness of Two Types of Friction Courses

North Carolina DOT

The North Carolina DOT conducted an analysis to determine the effectiveness of an open-graded friction course and a surface constructed with a FC-2 (friction course) gradation. Data from the pavement management database was used, including inventory data, construction information and pavement condition ratings. The performance data were plotted against the survey year for each pavement section where one of the two types of surface friction courses was applied. The results showed the performance of the open-graded friction course dropped at year 10, while the FC-2 graded surface dropped in performance at year 8. The study also found that all FC-2 sections had received another treatment by year 11. The results from the analysis were used to increase the use of open-graded friction courses across the state.

Practice Example
Improving South Dakota DOT's Pavement Deterioration Models

South Dakota DOT

In 2011, the South Dakota DOT initiated a project to revise the pavement deterioration models developed in 1997 using 17 years of historical pavement condition data. The tool for developing the models included features allowing all the condition-versus-age data points for each pavement meeting the family description (based on surface type and pavement structure) to be plotted on a graph, facilitating a comparison of the historical model and the recommended model based on the updated pavement condition information. In this example, the blue line (labeled as the user-defined model) represents the model being used in the pavement management system for predicting faulting on a thick, short-jointed doweled concrete pavement and the gold line (labeled as the regression equation). The regression analysis on the historical data, represented by the red data points, indicates faulting is occurring at a much more accelerated rate than was previously predicted. As a result, recommendations for addressing faulting were likely lagging the actual need observed in the field.

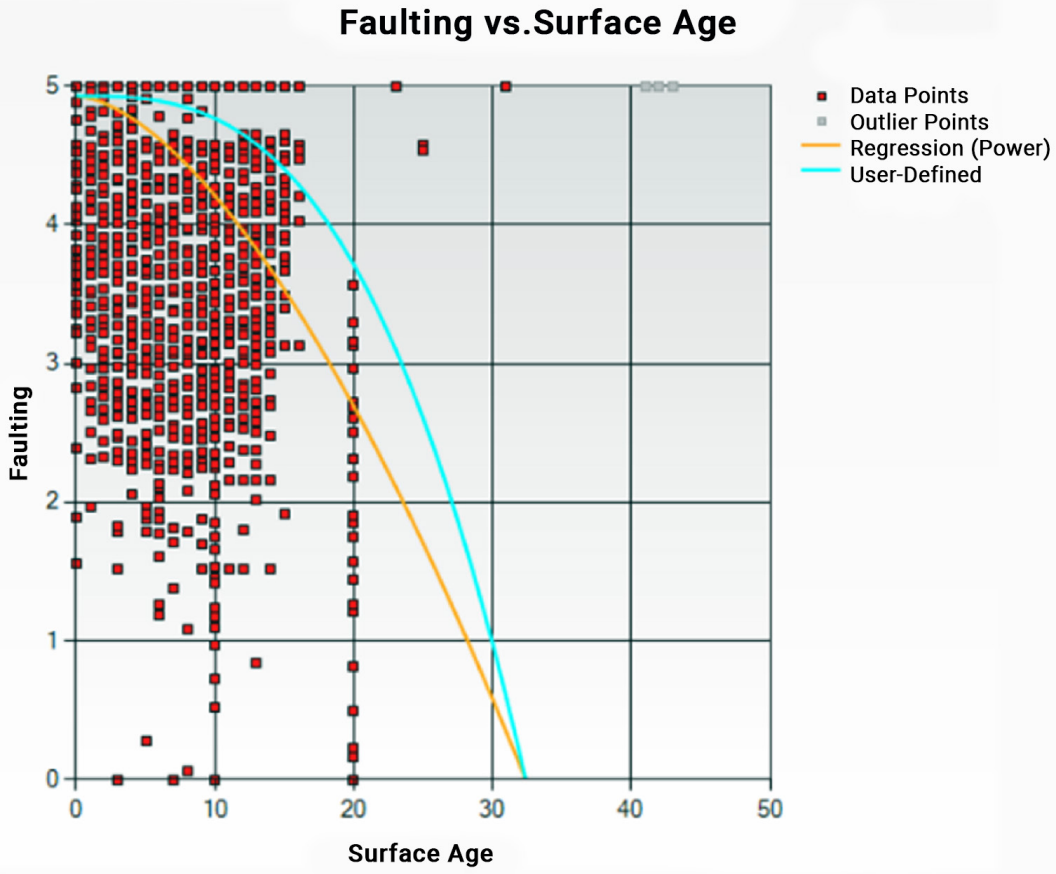


Illustration showing how historical data can be used to modify a deterioration model.
Source: South Dakota DOT. 2012. Technical Memo/Software Documentation

Practice Example
Evaluating the Effectiveness of Treatment Options

New Zealand Transport Agency

The Auckland Harbour Bridge corrosion protective coating system has been undergoing regular maintenance since the bridge opening in 1959. Historic practice was to spot abrasive blast corroded surfaces followed by spot painting and applying a full overcoat. While this process was effective in maintaining the protective coating, it also resulted in significant amount of contaminates being discharged into the Waitematā Harbour despite of the precautions being taken.

In an effort to reduce the discharge, various options have been considered taking into account the protective coating performance and longevity, with the aim to achieve the lowest practicable environmental discharge and whole of life costs.

One option involved collecting the abrasive blasting removal of the coating via the use of full scale containment to capture contaminants. However, it was found that this option would require strengthening of the bridge to safely carry the containment under wind loading at a cost of NZ$65M over a 10-year period.

As such, by undertaking a comprehensive review of the coating maintenance, a 40 years Coatings Maintenance Plan was developed. The identified lowest whole of life solution involved:

1. On the land spans, use of full containment (where it could be supported from the ground), allowing for the full removal of the coating system via abrasive blasting, and its full reinstatement. These spans are to be left as long as possible before reinstating the protective coating, while ensuring minimal, if any section loss, to the steel superstructure.
2. Spot repair and overcoating of other spans to maintain the existing coating for as long as practicably possible. A more proactive intervention approach is also adopted while using abseil techniques to minimise access costs.
3. An outcomes based approach for consenting purposes that involved the establishment of low level discharge limits for contaminants deemed to be environmentally safe. This enables small areas of abrasive blasting without full containment for spans other than above land.

Thus, allowing for the continued corrosion protection of the bridge 125,000m2 external surface areas in a marine environment, while providing a cost effective and environmentally responsible solution.

Source: https://www.icevirtuallibrary.com/doi/abs/10.1680/jbren.18.00051

Practice Example
Use of Historical Work Activities to Evaluate Fleet Management Strategies

Toronto Transit Commission

The Toronto Transit Commission initiated a review to determine optimal bus life for their fleet as well as assess the potential for hybrid propulsion technology. Through specialized modelling methods, a data-driven approach was used to assess the total cost of ownership (TCO) for their fleet vehicles. This review analyzed historical asset work order records along with other capital and operating expenses to help identify the optimal asset life cycle. The four key areas analyzed were:

- Procurement/Installation: Asset Design Specifications & Procurement Cost
- Operations & Maintenance: Labor, Parts, Fuel (if applicable), Consumable Items and Outsourced Work
- Overhaul/Rehabilitation: Major Asset Refurbishment/Component Replacement Cost (ex. Transit Bus Transmission Rebuild or Facility Rehabilitation)
- Disposition: Salvage Value (End-of-Life)

The model provided insights on when the optimal time to dispose of a fleet vehicle to minimize overall fleet cost, the comparative TCO of different vehicle types, and the relative effect and up-time benefit gained for different operations and maintenance activities or rehab treatments, by engine or other component types used in the fleet. They advanced their understanding of treatment effectiveness and allowed them to make more informed decisions about fleet renewal.

Practice Example
Use of Life Cycle Analysis to Improve Programming

Washington State DOT

The Washington State DOT conducted a pavement life cycle analysis using performance and cost data that demonstrated the cost-effectiveness of its pavement preservation projects. Based on the results that are documented in their Transportation Asset Management Plan (https://www.wsdot.wa.gov/sites/default/files/filefield_paths/WSDOT_TAMP_2019_Web.pdf), the DOT instituted a "one touch policy" requiring all capital projects to have had at least one pavement maintenance treatment by Maintenance or contracted work forces before it can be programmed for a pavement preservation project. This has enabled the DOT to defer capital improvements on pavements by two to three years, or in instances of multiple touches, by four to six years at a very low cost. In 2018, the agency received an additional $6 million to test a similar program on bridges. In addition to being a cost-effective use of available funds, the programs have helped build buy-in among maintenance personnel by demonstrating the importance of the data they collect.

Section 6.5

Monitoring Risks and TAM Processes

Chapter 2 introduced a process for identifying, analyzing, evaluating and managing risks, including a step for monitoring and reviewing risks on a regular basis. Since risks are constantly changing, it is important to establish processes to track changes in risks over time and monitor actions taken to manage risks. The same is true of other business processes that support TAM; they should be monitored regularly to ensure that analysis results continue to support investment decisions and that any gaps between desired and actual levels of maturity are addressed. This section introduces tools used to track and manage risks, highlights methods of monitoring and evaluating TAM processes, suggests a structure for assigning responsibility for implementation of new processes, and illustrates successful practices used in transportation agencies.

This section has three parts:

1. **Monitoring and Managing Risks.** This part introduces tools used to monitor and manage risks.
2. **Monitoring TAM Processes and Improvements.** This part describes the methods that can be used to help ensure that an organizations' TAM processes continue to effectively support decisions.
3. **Managing Implementation Responsibilities and Processes.** This part introduces methods and tools that can be used to ensure that responsibilities for managing risks and TAM improvements are understood and carried out successfully.

Monitoring and Managing Risks

Risk registers, risk reports, and risk mitigation plans are commonly used tools to track and manage risks. This section describes and illustrates each of these tools.

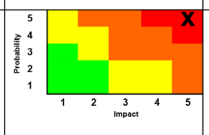
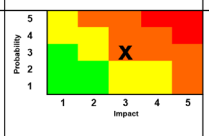
Risk Register

A risk register is one of the most common tools for tracking and managing risks within an agency, since it provides a framework for capturing critical information about each risk, its importance to the agency, mitigation plans and tracking and managing responsibilities. A risk register is typically generated as a spreadsheet, though other formats are available. An example of a comprehensive risk register, which includes assignments for risk mitigation strategies, is presented in Figure 6.5. Over time, columns may be added to indicate when the risk information was last updated, what further action is required and whether adequate progress is being made towards the mitigation strategy.

A risk register should be reviewed at least quarterly to evaluate whether the risk register or the risk management plan for any of the performance areas needs to be updated. Periodic changes to the risk profile may be obtained through executive staff meetings meant to evaluate progress regularly, or ongoing reports tracking risk mitigation efforts and results. Annually, the agency may determine whether any strategic-level risks should be adjusted based on evaluation of the agency's performance and the risk reports provided by the risk owners.

Figure 6.5 Excerpt from a risk register showing responsibility for risk mitigation activities

Risk Management Plan for Tillamook County Public Works Department

Risk Identification						Qualitative Risk Assessment			Management Plan					
#	Program	Risk Category	Failure Cause	Effect	Threat or Opportunity	Probability	Impact	Risk Matrix	Response	Risk Contingency Response Plan	Residual Risk	Actions	Responsibility	Resources
1	Roads	Paved roads	Lack of timely maintenance Insufficient funding Poor design Wet climate/storm damage Poor drainage Utility work Traffic loads Lack of enforcement Lack of staff	Pot holes, shoulder deterioration, poor public image, base deterioration, overgrown vegetation, detracting from property value, increase maintenance cost, increased congestion, increase property damage, hurts industrial development tourism	Threat	5	5		Mitigate	Fill pot holes and pave what we can on high volume streets (collectors & arterials)	Risk remains.	1.1 Report to board on risk and funding need. 1.2 Implement increased program if funds approved. 1.3 Develop Pavement Management Strategies	TCPW Director	1.1 TCPW Director 1.2 TCPWDirector & foremen & contract inspection
2	Roads	Gravel roads-county maintained	Lack of county maintenance Poor design Wet climate Poor drainage	Pot holes, shoulder deterioration, poor public image, base deterioration, overgrown vegetation, detracting from property value, increase maintenance cost, increased congestion, increase property damage, hurts industrial development tourism	Threat	3	3		Mitigate	Grade gravel roads Focus on higher volume roads with more residents	Risk remains.	2.1 Define gravel road priority based on connectivity and emergency routing. 2.2 Identify roads to transfer to other jurisdictions based on above. 2.3 Review/approve Board to transfer to partner based on above. 2.4 Proceed as possible based on available resources.	TCPW Director	2.1 TCPW Director 2.2 TCPWDirector & foremen & contract inspection

Source: Tillamook County Public Works Road Asset Management Plan. 2009

Practice Example
Managing the Risk of Unstable Slope Failure

Washington State DOT

The Washington State DOT recognized the potential safety risk to highway travelers and the adverse impact on regional commerce associated with unstable slope failure. To become more proactive in managing this risk, WSDOT developed the Unstable Slope Management System (USMS) that provides a method for evaluating known unstable slopes and using the information to prioritize slopes for funding of proactive stabilization efforts. The mitigation objective of the unstable slope management program is to sustain a desired state of good repair and low risk over the life span (> 20 years) of known unstable slopes and constructed geotechnical assets at the lowest practicable cost.

Risk Reports

Risk reports, which reflect excerpts from the risk register, may be developed by risk owners to communicate ongoing activities and manage risks at any level of the organization. The type of risk report shown in Figure 6.6 conveys what steps are being taken to address project delivery risks.

Risk Mitigation Plans

Some agencies see benefit in developing risk mitigation plans for their assets to ensure compliance with regulatory programs and help embed risk into all agency business activities. For example, a risk management plan may be developed when a bridge's risk of failure reaches a certain threshold. These plans identify specific risks and mitigation strategies to undertake in order to reduce the likelihood or impact associated with the risk.

Figure 6.6 Sample risk report

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

Source: AASHTO. 2016. *Managing Risk Across the Enterprise: A Guide for State DOTs*.

Practice Example

Local Hazard Mitigation Plan

Bay Area Rapid Transit Authority (BART)

BART developed a Local Hazard Mitigation Plan in 2017 to reduce or eliminate long-term risks to human life and property related to hazards such as earthquakes, tsunamis, landslides, flood, sea level rise, wildfire, and drought. The analysis focused primarily on high-priority fixed assets such as passenger stations, substations, switching stations, train control rooms, shops/yards, ventilation structures, and emergency exits. These assets were prioritized based on criticality in terms of the impact of an asset failure on reliable and safe service capabilities. The Local Hazard Mitigation Plan details the potential impacts associated with each hazard type and presents prioritized mitigation actions that were determined by votes from the participating members of a Task Force Committee called the Emergency Preparedness Task Force Committee (EPTFC) that is made up of senior managers from all BART departments. The plan is updated at least once every five years. The Plan has helped identify agency priorities that are being addressed and has fostered collaboration among different Departments to reduce potential hazards.

Checklist

Monitoring External Considerations in Risk

In the early stages of risk management, transportation agencies tend to focus primarily on identifying and monitoring internal risks that are within the agency's control. However, agencies should also monitor external considerations that may influence agency risk, including those listed below.

- ☐ **How will changes in technology impact the way transportation agencies operate in the future?**
- ☐ **What political or social trends are impacting the way we manage our transportation network?**
- ☐ **Is the frequency or intensity of weather events impacting the performance of our transportation network?**
- ☐ **As an agency, are we dependent on external sources to provide critical information for managing the network?**
- ☐ **Are trends in financial models indicating that revenue for transportation will be impacted dramatically in the next several years?**
- ☐ **Are there indications that regulatory or legal compliance issues are changing?**
- ☐ **As an agency, are there changes in the available workforce that will need to be addressed?**
- ☐ **Are there trends in contractor or vendor practices that could impact our ability to deliver our program?**
- ☐ **Are there changes in travel demand that are impacting the way the transportation system is managed?**

Monitoring TAM Processes and Improvements

As discussed throughout this Guide, TAM is an on-going process that needs to be monitored regularly to ensure that it continues to support an agency's business decisions. This section presents tools and methodologies used to accomplish this. It also builds on the application of some of the tools introduced in section 2.5.1, Assessing Current Practice.

Gap Assessment

A gap assessment is used to identify differences, or gaps, between an agency's practices with those suggested as part of an established asset management framework. The results of a gap assessment can be used to identify changes in business processes that are needed or can serve as the basis for developing priorities as part of an asset management implementation plan. The gap analysis tool available through the AASHTO TAM Portal is an example of a tool that can be used by an agency to assess practices so they can be compared to desired, or more established, practices. A summary of the gap analysis tool and other frameworks for assessing current practice was presented in Figure 2.6. An example of a chart showing targeted and current ratings in eight assessment areas over a 2-year period is presented in Figure 6.7. While the agency's targeted, or desired, scores remained consistently at a rating of 5 over both years, the graph is helpful for determining what assessment areas have improved over the 2-year period and which have not.

Lean Six Sigma

A lean six sigma framework uses statistical analyses as part of a continuous improvement approach to evaluate the cause of defects and methodically make improvements to processes to eliminate them. Six sigma is widely used in manufacturing sectors, but can also be applied to many TAM functions. For instance, a six sigma analysis would be useful in analyzing the root cause of defects associated with a poorly-performing asset. Combining a six sigma approach with a Lean framework, which focuses on reducing waste, can help agencies develop more efficient and sustainable processes.

ISO 33000 Process Assessment

The International Organization for Standardization (ISO) has introduced a variety of processes to support Asset Management. ISO 33000 is a standard for Process Assessment, providing a structured approach to help agencies better understand their processes, evaluate the suitability of their existing practices, and to determine the suitability of another organization's processes as a way of improving practices.

The Balanced Scorecard

The Balanced Scorecard approach was initially developed to enable organizations to make complex tradeoff decisions that balanced different types of performance criteria. For example, the framework could be used to help determine the tradeoff between improving the level of service provided in a corridor with

Practice Example
Application of Lean Six Sigma to Educate TAM Skeptics

New Brunswick Department of Transportation and Infrastructure

The New Brunswick Department of Transportation and Infrastructure (NB DTI) implemented Lean Six Sigma to better understand and document existing practices and identify where improvements could be implemented for savings or service improvement. The Lean Six Sigma methodology helps to improve performance through a collaborative process that systematically removes waste and reduces variation while improving customer satisfaction. For NBDTI, the application of this methodology has resulted in increased efficiency, cost savings, refined procurement methods, improvements to delivery of operational programs and services, and has supported the application of asset management decision-making to pavements, bridges, culverts, facilities and other transportation infrastructure.

improving environmental sustainability on a statewide basis. The balanced scorecard analysis takes a holistic and balanced approach to these types of issues, by simultaneously evaluating competing and dissimilar needs (such as Customer Satisfaction, Sustainability, and Safety). The advantage to the balance scorecard approach is the fact that multiple measures are considered, rather than a single set of measures that might disregard an important factor in the decision. The results produce a rational set of investment decisions that considers all of the factors that the agency views as most important to the final selection.

Figure 6.7 Example comparing assessment area scores from two different rating periods

Source: AASHTO. 2015. *Transportation Asset Management Gap Analysis Tool User Guide*

Managing Implementation Responsibilities and Processes

Monitoring the implementation of new business processes benefits from a clear definition of roles and responsibilities. This section illustrates approaches that agencies use to assign responsibility for implementation activities so that progress can be tracked.

Assigning Responsibility for Managing Risks and Implementation Activities

A key step in managing risks and other implementation activities is establishing a set of roles and responsibilities for each of the tasks at hand. The risk management process introduced in Chapter 2 includes a step for monitoring risks on a regular basis through a risk register or some other format.

Risks

When assigning responsibilities for managing risks, different types of risks are normally assigned to different individuals or divisions within a transportation agency:

- **Strategic risks –** Impact the agency's ability to achieve its goals and objectives. Ignoring risks at this level can cascade down to impact programs and projects at other levels of the agency. For this reason, strategic risks are generally assigned to members of agency leadership and may be addressed by incorporating risks into regular management meetings and key policy documents.
- **Program risks –** Impact an organization's ability to administer a program in a coordinated way. Risks at this level are typically the responsibility of the program manager ensuring there are effective controls over risk and documenting risk activities.
- **Project risks –** In many agencies, a project risk management process is in place with responsibility for managing risks assigned to the project manager. At this level, primary responsibilities include managing risks associated with the project scope, schedule and quality.
- **Activity risks –** Associated with routine activities performed by the agency, such as snow and ice control, incident response and pavement management modeling. Risks at this level are typically managed and monitored by the activity leader.

An agency may elect to appoint a Chief Risk Officer or to create an Enterprise Risk Unit charged with coordinating the agency's risk processes and training agency personnel on risk management. If such a unit is created, the Chief Risk Officer often reports directly to the agency's chief executive officer or another high-ranking executive, symbolizing the importance of risk management to the agency. Agencies without a formal Risk Unit may rely on the Asset Management Coordinator to serve in this role. Examples showing how risk roles and responsibilities have been assigned are provided in Figures 6.8 and 6.9.

Process Improvements

The success of a TAM Improvement Plan that outlines steps the agency plans to take to enhance its asset management program will also benefit from a clear set of roles and responsibilities for:

- Implementing the suggested changes,
- Monitoring progress, and
- Repeating the assessment periodically.

Ownership for the implementation of the planned enhancements generally lies with

the TAM Coordinator in an agency, with specific tasks assigned to one or more individuals with the specialized skills and capabilities that are needed.

A major function of the implementation leader is to ensure that all roles are understood and that the various assignments are being carried out as intended. This may require building buy-in among the team members, who are likely busy with other responsibilities. It is also important that the leader have the authority responsibility to hold individuals accountable for progress, even if they report to a different division within the agency.

Figure 6.8 Risk types and owners

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

Source: Transportation Research Board. 2014. *Managing Risk Across the Enterprise: A Guide for State DOTs.*

The availability of adequate resources is also important to the successful implementation of an improvement plan. Establishing clear role descriptions that describe the required tasks to be completed and the requirements needed to implement the changes enables an agency to compare the availability of existing staff to the implementation requirements. In some instances, staff may be temporarily assigned responsibility for a particular activity, such as developing a TAMP, to address a specific need.

Using a RACI Matrix to Assign Roles and Responsibilities

A variety of tools can be used to track roles and responsibilities, including spreadsheets or various type of matrices. One form of responsibility assignment matrix is known as a RACI matrix. The term RACI is taken from the words:

- **R**esponsible. Assigning responsibility for getting the work done or making a needed decision. This is typically the person who gets the work done.
- **A**ccountable. Identifying the person who is responsible for making sure the work is done and is ultimately answerable for the activity or decision.
- **C**onsulted. Recognizing that others will provide information needed to complete an activity.
- **I**nformed. Keeping people aware of progress that is made.

A RACI matrix can be used for virtually any type of activity with a combination of tasks, milestones, and key decisions that will be carried out by several different individuals. It is a common technique used for managing different types of construction, implementation, and monitoring activities and is especially useful when responsibilities are divided across divisions or departments within an organization. For that reason, it is commonly used as part of an enterprise-wide risk management program to help ensure that risks are monitored regularly. An example of a RACI matrix showing responsibilities for adopting an enterprise risk management (ERM) policy is shown in figure 6.10.

Figure 6.9 Risk management roles and responsibilities for the Highways Agency, England

Exhibit 7-2 Project Risk Management Plan Duties

Project Manager	• Approve the project RMP. • Approve and ensure implementation of response actions to identified risks, particularly significant risks that emerge as prospects for risk response. • Confirm who will carry out response actions and when action will be taken; incorporate into work plan. • Monitor effectiveness of response actions. • Regularly review and update the project RMP. • Promote aggressive risk management for this project. • Actively participate in risk workshops. • Communicate to senior management the risk and uncertainty the project is exposed to and the action that will be taken to address it.
Project Team Member	• Proactively identify risks and their characteristics in terms of probability of occurrence and impact. • Proactively respond to risks within specialty area. • Document actions and report to Project Manager for inclusion in risk management updates. • Monitor effectiveness of response actions. • Communicate with Project Manager regarding risk management actions and changing project risk profile (addition of new risks or retirement of old risks –as appropriate).
Project Risk Manager	• Prepare and update the project RMP. • Develop a schedule for key check-in milestones for review and update of the RMP. • Determine when risk workshops will be needed and ensure appropriate preparation is accomplished prior to the workshop. • Collaborate with the Strategic Analysis and Estimating Office, CREM Unit, to coordinate pre-workshop, workshop, and post-workshop activities, including the need for consultants and/or other participants—both internal and external. • Oversee and manage day-to-day risk management process for the project. • Ensure quality of risk data. • Track and monitor effectiveness of response actions. • Promote risk management activities within the project team and with stakeholders. • Communicate with Project Manager on all matters related to risk
Risk Owner (Action Owner)	• Implement agreed response actions. • Report on effectiveness of the risk actions to the Project Manager/Risk Manager and affected project team members. • Identify new risks that may emerge after response actions. • Communicate with Project Manager regularly, including the need for other risk response actions if needed.

Source: Washington State DOT. 2018. Project Risk Management Guide.

Figure 6.10 Example RACI chart

Responsibility for ERM

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

Activity: Adopt ERM Policy

PROCEDURE: Draft, Distribute, Adopt ERM Policy

DEPARTMENT: Director

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

Activity: Appoint ERM Coordinator

PROCEDURE: Assign staff responsibility for ERM process

DEPARTMENT: Director

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

Activity: Develop Risk Tools, Process

PROCEDURE: Provide staff risk tools, identify risk processes

DEPARTMENT: Risk Coordinator or Risk Manager

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

Source: AASHTO. 2016. *Managing Risk Across the Enterprise: A Guide for State DOTs.*

Practice Example
Use of a RACI Matrix for a Cross-Discipline Process

City of Seattle DOT

The City of Seattle has a Sidewalk Safety Repair Program to oversee the maintenance of the City's many sidewalks and curbs to keep them safe and accessible. The Program includes a process for monitoring sidewalk conditions, investigating complaints of unsafe or inaccessible sidewalks, determining repair responsibility (e.g.., adjacent property owner, City, or other utility), using existing conditions to proactively mitigate conditions (beveling and asphalt shimming), and permanently repairing sidewalks that are the City's responsibility. Repairs are leveraged with other capital projects as much as possible, so coordination with other Divisions is vital to the effectiveness of the program.

Because of the number of Divisions involved in managing sidewalks, the City assigned roles and responsibilities in a RACI matrix, that identifies those with Responsibility (R) or Accountability (A), those that need to be Consulted (C), and those that need to be Informed (I). The RACI matrix developed by the City includes one additional role beyond the four that are commonly included in the matrix. The City of Seattle added an "S" to represent a support role for personnel who might provide information to the process but are not necessarily responsible for completing the activity. The RACI matrix has served the City well by clarifying the responsibilities of each of the Divisions involved in some aspect of the Program so the program looks seamless to the public, as shown on the City's website (https://www.seattle.gov/transportation/projects-and-programs/programs/maintenance-and-paving/sidewalk-repair-program).

Key
A - Approval
R - Responsible
C - Consulted (Review)
S - Supports Task
I - Informed

Task / Subtask	Asset Owner, MOD	Urban Forestry Staff, MOD	Maintenance Crews, MOD	Asset Data Specialist A&PM	Finance Staff, FAD	ADA Coord, CPRS	Project Staff, CPRS	RWS Crews, CPRS	Project Staff, TO	Traffic Data Analyst, TO	Program Staff, PD & TM	Permit Techs/Inspectors, SU	P&P Staff	IT, GIS Support	IT, Hansen Support	COMMENTS/ SPECIAL CASES
Coordinate resource and asset management strategies for operation and maintenance	R	I		C	S	R			C		C		S			
Identifies funding priorities for repair program based on established criteria	R	I		C	S	R			C		C		I			Maintenance budgets have historically maintained a static level of under-funding. This includes a commensurate funding to support new assets. To fully support asset upgrade requests of the existing assets, this agreement recommends sufficent funding to meet the demand.
Responds to questions about existing assets and plans for maintaining those assets	R			S		R			S		S		S			
Resolves identified issues	R			S		R			S		S		S			Informs other staff as needed
Tracks asset inventory, value, and condition	S			R		S			S		S		I			
Investment scenarios for preservation, maintenance and operations based on existing and projected inventory	R			S		R			C		C		I			
Primary source of information & knowledge about the asset, its condition, its performance & capabilities	R			S		S			S		S		I			
Identifies & prioritizes locations where TO programs will build or upgrade new sidewalks & ramps				S		S			R							
Identifies & prioritizes locations where PD & TDM programs will build or upgrade new sidewalks & ramps				S		S			S		R					
GIS Maps	R	S		S		R			S	C	S	C	S	S		
CADD Drawings	I			I		R			R		R	R				
Train staff on Hansen 8 Asset Module				R												

Excerpt from a RACI matrix developed by the City of Seattle for managing roles and responsibilities for its Sidewalk Repair Program
Source: City of Seattle. 2019.

Checklist

Risk Management Process

The successful monitoring and enhancement of a risk management process or other TAM business processes requires a concerted and coordinated effort throughout the organization. To help ensure success, agencies can consider the following important factors.

- ☐ **Do you have a structure with clear roles and responsibilities that are coordinated across the agency?**
  - ☐ The roles and responsibilities required to support a TAM program will change over time as the agency matures. Initially, an agency may start with a small, concentrated team of individuals supporting TAM, but as the process is embedded in the agency's practices, the number of involved team members may grow.
  - ☐ TAM is a cross-disciplined practice that requires strong coordination and a clear strategy to keep everyone aligned.
- ☐ **Do you have the right resources to implement your plans and programs?**
  - ☐ A lack of available resources can cause the implementation of TAM to fail, so ensuring that the right resources are available may require the support of upper management.
  - ☐ The implementation of risk management and TAM often require changes in the way an organization is doing business, so training programs may be needed to ensure staff can be effective and that they have confidence in making the changes necessary.

How-to

Use RACI To Create a Responsibility Assignment

A RACI matrix is a tool used to identify roles and responsibilities to ensure that tasks or activities are completed. The term RACI is taken from the words:

- Responsible. Assigning responsibility for getting the work done or making a needed decision.
- Accountable. Identifying the person who is responsible for making sure the work is done.
- Consulted. Recognizing that others will provide information needed to complete an activity.
- Informed. Keeping people aware of progress that is made.

The development of a RACI matrix includes the steps listed here.

1. Identify project roles or participants.

Along the top of the chart list all individuals who will be involved in the process or list the roles that will be needed.

2. Identify project tasks, milestones, and decisions.

List these along the left-hand column. List all key tasks, milestones, and/or decisions in the chart, but don't get so detailed that it becomes a to-do list (like listing team meetings).

3. Assign roles for each task and deliverable.

Using the RACI model, assign to each task one individual who will be accountable for making sure the work is done and one or more people who will be responsible for completing the work. Identify individuals or roles who should be consulted while the task is ongoing and who should be informed once the task is complete.

4. Get buy-in for each role and responsibility.

Be sure that everyone agrees to the roles and responsibilities assigned for the project.

5. Use the RACI matrix to monitor progress and make necessary adjustments.

Creating a Responsibility Assignment

1. Identify project roles or participants
2. Identify tasks, milestones and decisions
3. Assign roles for each task and deliverable
4. Get buy-in for each role and responsibility
5. Use RACI matrix to monitor progress

Maturity Scale

This table provides an example maturity scale for some of the key TAM practices described in this chapter.

Aspect of Practice	Level of Maturity	Typical Agency Status
Performance Measurement and Management	Emerging	• Some key performance measures are established within the organization and are beginning to be measured. • Performance measures are periodically reviewed and enhanced over time. • Regular reporting of progress with trends tracked over time.
	Strengthening	• Performance measures are established within the organization and provide a strong linkage between. agency objectives and the processes for capital decisions. • Regular reporting of progress with clear trends indicating improvement.
	Advanced	• Performance measures are well established within the organization and provide a strong linkage between agency objectives and the processes for capital and operational decisions. • Performance measures are directly used to prioritize investment needs. • Regular reporting of progress with clear trends indicating significant improvement over time.
Monitoring the State of Assets	Emerging	• Asset data collection and management is in transition to better support timely and accurate performance reporting.
	Strengthening	• The performance measurement framework is evolving to improve goal alignment and trend the agency to desired outcomes. • Asset data collection and management supports performance reporting.
	Advanced	• Periodic review of performance measurement framework is carried out to confirm measures are appropriate, aligned with objectives and suitable to trend the agency to desired outcomes.
Monitoring Funding and Resource Allocation Methods	Emerging	• Trend analysis is employed by the agency to help identify potential adjustments to improve performance targets.
	Strengthening	• Trend analysis and other analytical tools are being trialed by the agency to help identify potential adjustment actions to improve performance. • Current status is understood by all internal stakeholders, and resource allocation in some departments is supported by informed decision-making.
	Advanced	• Trend analysis, performance forecasting and other analytical tools are employed by the agency to help identify potential adjustments to operational, tactical or strategic actions to help achieve performance targets. • Current status is understood by all internal and external stakeholders, and resource allocation is supported by informed decision-making.
Monitoring Asset Work and Costs	Emerging	• The agency is improving its ability to track operations and maintenance costs and capital investments and link them to assets in the portfolio. • Some departments can analyze the effectiveness and efficiency of their alternative interventions.
	Strengthening	• The agency tracks operations and maintenance costs and capital investments, and these are linked to the asset to which they apply. • Analysis is periodically carried out to assess efficiency of alternative interventions.
	Advanced	• The agency has accurate method of tracking operations and maintenance costs and capital investments, and these are linked to the asset to which they apply. • Analysis is periodically carried out to assess the effectiveness and efficiency of the alternative interventions and trade-off between maintenance and capital decisions.

Maturity Scale

Aspect of Practice	Level of Maturity	Typical Agency Status
Tracking and Managing Risks	Emerging	• The agency has identified some operational risks, manage them in a risk register and have established targeted mitigation strategies.
	Strengthening	• The agency has an integrated risk management framework that allows risk to be employed at a more than one level within the agency. • High risks are proactively managed or leveraged.
	Advanced	• The agency has an integrated risk management framework that allows risk to be employed at strategic, tactical, and operational levels. • Risks are proactively managed or leveraged. • Managed risks show reduced frequency of negative consequences or opportunities are captured as appropriate. • TAM processes are evaluated regularly for improvement.

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