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Section 1.1

TAM Basics
covers the definitions used throughout the guide and discusses the high-level principles, elements and benefits of good TAM practice.

Section 1.2

About This Guide
provides an overview of the organization and features of the guide.

Section 1.3

TAM Resources
provides a brief summary of the resources used throughout the Guide and indicates how to access the resources.

Chapter 1
Introduction

Welcome to the Transportation Asset Management (TAM) Guide. Whether you are new to asset management, a seasoned practitioner or an executive, this Guide will help to further your understanding of asset management techniques and advance asset management practices at your agency.

TAM is a way of conducting a transportation agency's business to deliver more value in its activities so that the transportation system performs best with the available resources. Most agencies have elements of TAM principles in their existing practice. This guide can help with formalizing TAM practice, identifying areas for improvement, and understanding how to improve. Some of the benefits of TAM include:

- **Improved asset condition, performance, resilience, and longevity.** Asset management involves maintaining the asset condition over the asset's life time. Improved condition results in improved performance and ultimately extends the life of an asset compared to the alternative of continually deferring maintenance.
- **Improved accountability.** When asset management practices are embedded in an agency, staff are held accountable within the agency and to customers and stakeholders to follow TAM practices and consistently maintain the assets in a state of good repair. Preparing an asset management plan also ensures accountability by providing reliable information about the condition of assets.
- **Increased efficiency and effectiveness.** When assets are managed following an agreed upon management strategy, efficiency and effectiveness are improved. Regular maintenance can be planned and scheduled, reducing disruption to service as little as possible.
- **More benefit for each dollar invested.** Transportation assets cost money to build, maintain, operate, and use. By stressing the importance of life cycle planning and costs, and placing agreed levels of service at the core of the asset management process, TAM helps to ensure that the benefits delivered by the network are maximized, while the costs of providing, maintaining, and using it are minimized.
- **Reduced risk exposure.** When assets are maintained and managed consistently and resilience is improved, the agency reduces the exposure to risk.
- **Improved coordination and efficiency.** Asset management helps potential silos within an agency by improving resource allocation and improving coordination between staff on asset management related projects and maintenance.

Section 1.1

TAM Basics

For those new to asset management, this section is the place to start. In order to provide a solid foundation in asset management, this section provides definitions for key terms used throughout the guide, describes the principles of TAM, the elements of good TAM practice, and the benefits of asset management.

This section has four parts:

1. **What is TAM?** This definition and overview of TAM provides context and background on asset management and its place within transportation agencies.
2. **Definitions.** Key terms that are used throughout the Guide.
3. **TAM Principles.** A summary of the key principles of TAM.
4. **TAM Elements.** A summary of the key elements involved in TAM.

What is TAM?

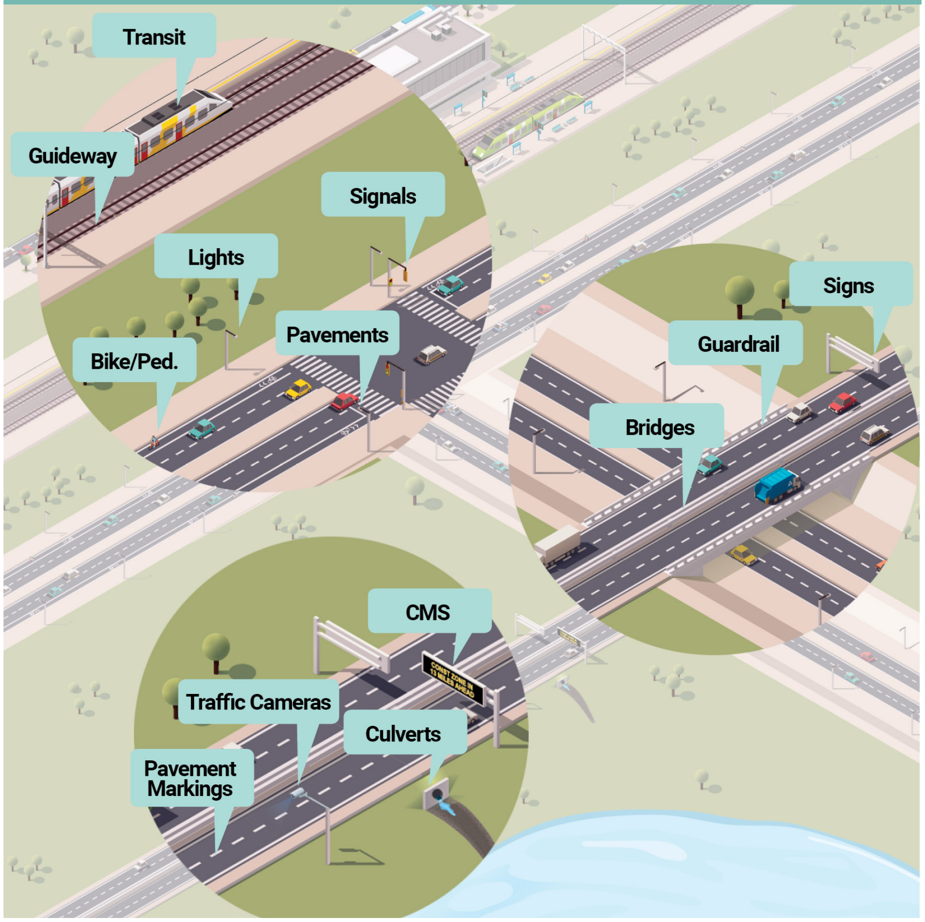
As defined by the American Association of State Highway Transportation Officials (AASHTO), TAM is a "strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well defined objectives."

TAM is important because of the size and value of the infrastructure that has been built. The total value of the existing inventory of U.S. transportation assets is staggering; based on data from FHWA Highway Statistics, the replacement value of U.S. bridges and pavement alone is over $5 trillion. TAM offers a set of tools and techniques applicable to sustain the condition and performance of the full range of transportation assets.

TAM has been a focus area for DOTs in the U.S. for over 15 years, paralleling similar efforts to improve asset management in infrastructure-intensive industries in the U.S. and abroad. Over this period, transportation agencies have worked to increase their understanding of the value and performance of existing assets; and implement improved asset management systems and approaches.

This guidance responds to the new challenges that have emerged since TAM was first recognized as a critical area in the U.S. transportation community such as: evolving business practices, technology advancements, constrained funding, changing environment, and legislative requirements.

Figure 1.1 Common Highway Assets



Definitions

It is important to establish key terms that are used throughout the Guide. While many of these terms have multiple or nuanced definitions, the definitions listed here are the assumed meanings used in the context of this Guide. Each chapter also lists important terms that expand on this list.

Transportation asset management (TAM) is defined by AASHTO as a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well defined objectives.

FHWA defines TAM similarly, stating, "Asset management is a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair (SOGR) over the lifecycle of the assets at minimum practicable cost."

In the International Standards Organization (ISO) Standard 55000, asset management is defined as the "coordinated activity of an organization to realize value from assets. Realization of value involves the balancing of costs, risks, opportunities and performance benefits." In addition, the ISO standard states that, "Asset management enables an organization to examine the need for, and performance of, assets and asset systems at different levels. Additionally, it enables the application of analytical approaches towards managing an asset over the different stages of its life cycle (which can start with the conception of the need for the asset, through to its disposal, and includes the managing of any potential post disposal liabilities)."

Performances measures are quantifiable metrics that are used to track progress toward goals, objectives, and established performance targets

A **performance target** is a level of performance desired to be achieved within a specific time frame.

State of good repair (SGR) refers to a condition in which existing physical assets, both individually and as a system, are functioning as designed within their useful service life and are kept functional through regular maintenance and replacement programs.

Levels of service are an agency's stated commitment to deliver asset service at a specified level of quality and reliability. Service levels can be asset performance-related or customer/regulatory-related (complaints, meeting regulatory requirements). These levels of service can include, but are not limited to, the historic "level of service" used to grade traffic congestion.

Asset condition refers to an asset's current state, as specifically defined by its appearance, perceived level of service, and observed physical state, whether or not it impacts its performance.

Risk is the positive or negative effect of uncertainty or variability upon agency objectives. [23 USC 515.6]

Life cycle planning and management is a process to estimate the cost of managing an asset class, or asset sub-group over its whole life with consideration for minimizing cost while preserving or improving asset condition. [23 CFR 515.5]

Whole-life costing is the systematic consideration of all relevant costs and revenues associated with the development, operations, and maintenance of the asset.

Reliability-centered maintenance is a structured, risk-based approach for determining the maintenance requirement for any physical asset, based on its operating context within the agency.

Resource allocation is the process of assigning scarce resources to investments in transportation assets. The assigned resources can be money, staff time, contractor capacity, equipment, or other organizational requirements for assets. The investments can be capital projects, maintenance efforts, or other projects and activities that require the use of an organization's resources through various delivery methods.

TAM Principles

The foundation of a good TAM program is a set of principles that establishes the values of the agency and the standards by which the TAM program will be carried out. TAM principles are the underpinnings of all of the activities that will be taken in an agency's TAM program and connect to its desired end results.

Policy-Driven. TAM should capture and respond to policy objectives, and provide meaningful information about how changes in the transportation system support these objectives. A TAM policy can set boundaries, clarify intent, and communicate the scope of a TAM program including types of assets that will be managed and what work activities to emphasize.. [NCHRP 551]

Performance-Based. TAM should have concrete objectives that are translated into system performance measures used for both day-to-day operation and longer-term strategic management. The use of performance data to support the management of assets enables agencies to select and deliver projects that achieve its objectives. Transparent processes allow for accountability to both internal and external stakeholders.

Risk-Based. Risk management plays a role in resource allocation, project selection, long-term planning and other essential parts of the TAM process. As such, an organization's approach to risk management and the outcomes resulting from a risk assessment have important implications for TAM. An agency must establish a risk management approach and integrate risk management in TAM planning and decision making.

Strategically Aligned with Agency Priorities. TAM measures should be aligned with agency priorities and goals to ensure that investments made to extend asset service life provide the maximum impact to achieve long-term goals. Connecting performance measures to higher level strategic goals also supports an agency's ability to communicate to customers and stakeholders how technical measures relate to system performance.

Transparent. TAM planning and results should be monitored and reported for both impact and effectiveness. Feedback on actual performance should influence agency goals and objectives, as well as future resource allocation and project decisions. Transparency and agency accountability are key in ensuring the long-term support of project partners, customers and stakeholders.

Information-Driven/Evidence-Based. Strategic decisions with respect to agency goals and TAM objectives should be evaluated using credible and current data. Decision support tools such as management systems should be applied to help in accessing, analyzing and tracking data, and must be an integral part of business and decision processes. Data requirements for performance measures should be realistic and feasible. [NCHRP 551]

Option Oriented. By taking a structured and repeatable approach to TAM decision-making, an organization improves its own resilience and ensures that it will continue to succeed even as new challenges arise and personnel changes over time.

TIP **Most agencies have elements of TAM principles in their existing practice. This guide can help with formalizing TAM practice, identifying areas for improvement, and understanding how to improve.**

Continuously Improved. TAM processes should provide managers with sufficient information to understand problems and suggest solutions. The agency should be committed to regular, ongoing processes of monitoring and reporting results in order to identify and implement improvements to system performance or further the effectiveness of TAM. [NCHRP 551]

TAM Elements

Asset management encompasses the full set of business processes related to the management of physical assets. There are several key TAM elements listed below that offer the greatest opportunity to improve an agency's asset management efforts.

Monitoring the state of the assets and developing desired and expected Levels of Service (LoS). Performance measures are used 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 or maintenance LoS. LoS provides the link between agency goals and the investments and interventions that should take priority when managing assets.

Maximizing use of available revenues. Agencies are faced with the problem of determining how to divide scarce resources between different asset types, in order to accomplish a variety of different objectives. TAM planning offers processes to help make these resource allocation decisions, such as Multi-Objective Decision Analysis (MODA)), long term financial planning, and Life-Cycle Planning.

Monitoring and managing risk. In TAM, uncertainty complicates efforts to make decisions about the future and forces agencies to be nimble so as to effectively respond to unpredictable events and evolving conditions. An organization's approach to risk management and the outcomes resulting from a risk assessment have implications for TAM. It is important to establish processes to track changes in risks over time and monitor actions taken to manage risks, through tools such as a risk register and/or a risk mitigation plan.

Investing in asset maintenance. State DOTs can specify their desired SGR, consistent with their TAM objectives, for the 10-year analysis period of their TAMP. This strategic long-term maintenance strategy helps agencies minimize the life cycle costs of preserving assets, while also managing asset performance to a defined target to the extent practicable with available resources.

Understanding the potential for asset failure and developing intervention strategies. Being aware of the potential for asset failure and making strategic investment decisions can help agencies prevent failures, reduce costs, and maintain a desired level of service. Over an asset lifecycle, a range of interventions are possible, from reactive, routine and preventative maintenance, to large investment associated with renewal, replacement and disposal.

Allocating resources and prioritizing work based on both short and long-term performance. The resource allocation process should support achieving short- and long-term goals. An agency must establish what scarce resources must be allocated, and what the constraints on these resources are. A key part of the process is to translate goals and objectives into performance measures so the agency can set target values for key measures and/or establish a target level of service.

Continuous improvement based on feedback. An agency should have regular, ongoing processes of monitoring and reporting results in order to identify and implement improvements to system performance or further the effectiveness of the performance management process. Ongoing monitoring, improvement and/or problem identification should be incorporated into the planning process to help adjust and determine future targets and processes.

Aligning the organization. Successful TAM depends on the alignment of a diverse set of internal business units and external partners and stakeholders. Strategic coordination and communication can bring these people and groups together to achieve TAM goals. In addition, the choice of a TAM organization model is important, and should align with and support agency policies and priorities.

Checklist

Basic Requirements Checklist

This checklist describes the basic requirements of a successful TAM program. Agencies can use this checklist to identify priority areas for TAM improvement efforts.

- ☐ **Leadership Support.** For TAM objectives to be understood and observed throughout the organization it is important to have access to senior leadership, and to be able to work with and get attention from leaders when needed.
- ☐ **Agreement on TAM objectives and scope.** An agency's planning, programming, asset owners, project development and delivery, maintenance, and other units must coordinate to make TAM work. It is crucial to have cross-agency agreement on TAM goals and performance measures.
- ☐ **Designation of key asset management roles.** Understanding what roles and responsibilities are most important for the TAM program is key to getting an agency ready and aligned to achieve TAM-related goals. Agencies must fill each TAM-related role with qualified people who possess the right competencies.
- ☐ **Internal and external coordination mechanisms.** In order to deliver mobility to the public, State DOTs must coordinate internally and with other agencies that own and operate transportation facilities. It is up to the agencies to work together either by forming committees, creating partnerships with external organizations, or developing communication strategies to reach all relevant stakeholders.
- ☐ **Current and reliable inventory and performance data.** TAM decision-making must be based on credible and current data. Data requirements for performance measures should be realistic, feasible and up to date with respect to asset conditions, as well as current technological requirements and advances.
- ☐ **Functioning analytical tools for major assets.** Decision support tools such as management systems should be applied to help in accessing, analyzing, and tracking asset data, and must be an integral part of an agency's business and TAM decision processes.
- ☐ **Work tracking processes (for system updates).** Agencies must have systems and data collection processes that are measured consistently, collected economically, and updated regularly.
- ☐ **Risk monitoring and management processes.** Monitoring risks to TAM requires clear definitions of ownership for the risks, the mitigation strategies, and the risk management processes. Different mechanisms can be used to address risks, such as risk registers or risk mitigation plans.
- ☐ **Performance monitoring and reporting processes.** Monitoring performance of the asset management system and the results of improvement actions can be challenging, as the cost of service delivery, quality of service levels and risk of service failures can change following implementation. For this reason, it is important that agencies select measures to monitor the effects of improvements that capture all of these aspects.
- ☐ **The TAMP development process.** Agencies need to have a process for preparing a TAMP and then monitoring its implementation. Agencies can create a task group to provide oversight through regular updates, meetings, performance tracking, and schedule monitoring.
- ☐ **Continuous improvement process.** It is necessary for an agency to ensure that asset management practices are reviewed on a regular basis to identify opportunities for innovation and advancement.

Section 1.2

About This Guide

This section orients the reader to the contents of the Guide and describes the framework used to organize the document.

This section has three parts:

1. **Scope and Organization.** Describes the organizing framework for the Guide and the contents of each chapter.
2. **Intended Audiences.** Describes the different audiences for the Guide.
3. **Ways to Use this Guide.** Provides information on the features of the Guide.

Scope and Organization

This Guide is organized around the basic asset management framework illustrated in Figure 1.2. This framework is tailored for use by U.S. transportation agencies and incorporates critical areas deemed important to the daily application and advancement of TAM practice.

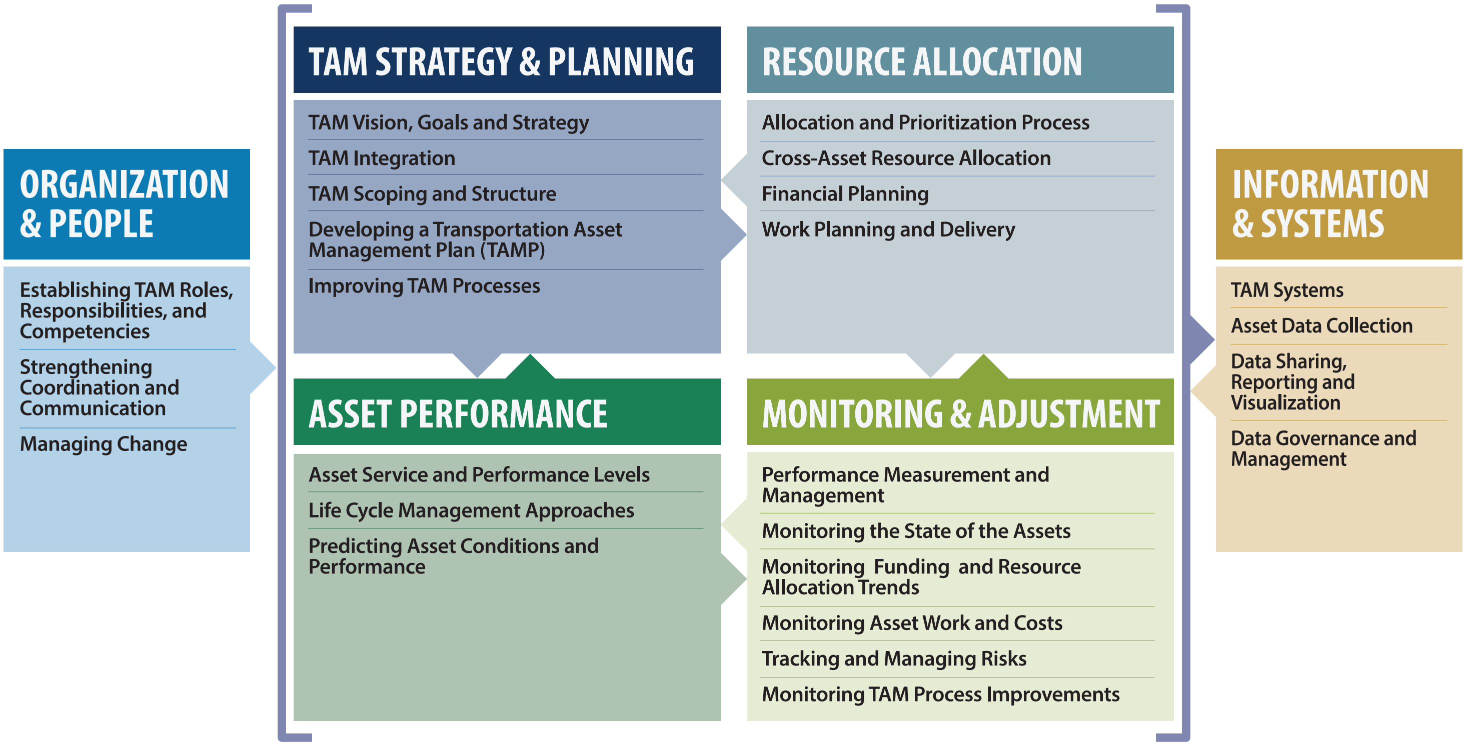
The framework shown in Figure 1.2 groups the components of asset management into six basic areas. The four central areas in the figure capture the business processes involved in asset management.

- **TAM Strategy & Planning.** An organization manages its assets not as an end in and of itself, but to achieve broader goals. These goals might include improving mobility, enabling economic growth, and reducing costs to travelers and the environment. It is important to place TAM in the context of an agency's broader goals and objectives, establish the scope of an agency's TAM effort, and determine how TAM integrates with the other activities performed by the agency. A Transportation Asset Management Plan (TAMP) helps establish this context, and preparing such a document is consistent with best practices in TAM. Additionally, U.S. State transportation departments and transit agencies are now required to develop TAMPs to comply with Federal requirements.
- **Maximizing the Life Cycle Performance of Transportation Assets.** This term encompasses the set of processes involved in determining how to manage an asset over its entire life, from construction or acquisition to maintenance and finally asset replacement or disposal. It addresses how to measure the level of service an asset is achieving and targets to achieve, how to best maintain an asset, and how to model the condition and performance of an asset in the future.
- **Resource Allocation.** Managing assets requires determining how to best deploy a set of finite resources, including staff time, equipment, and budgets for operating and capital expenses. This area includes the processes involved in making resource allocation decisions, both for a given asset class, and across multiple asset classes considering a range of different objectives and constraints. Also, it addresses the development of financial plans summarizing expected sources and uses of asset management funds. TAM financial planning takes a long-term view of resource allocation to support the delivery of strategies that address asset needs at all stages of their service lives.
- **Monitoring and Adjustment.** Ideally an organization's approach to TAM and TAM-related decisions should be dynamic, with adjustments made in response to available data on asset conditions. This area includes processes related to measuring and monitoring asset performance, assessing risk, and making adjustments to investment decisions and business process to respond to changing conditions.

The remaining two areas detail factors that enable an improved asset management approach. The two enablers of an improved asset management approach are:

- **Information & Systems.** TAM is very data intensive. It is important to have systems for tracking an organization's inventory of assets and collecting needed data

Figure 1.2 Guide Organizing Framework
Adapted from the Institute for Asset Management (IAM)



Source:

on asset conditions. Also, systems are often needed to connect to related data, including financial data and records of maintenance work. However, collecting asset data and implementing asset management systems can be costly and time consuming. It is important to develop an approach to information management that carefully considers what data are needed to support the organization's goals, and how best to collect needed data.

- **Organization & People.** All infrastructure-intensive organizations practice asset management in some manner. However, implementing a robust asset management approachincorporating best industry practices and a philosophy of continuous improvement requires having a robust organization and people with the correct mix of skills. Creating such an organization requires defining roles and responsibilities for TAM within an organization. Also, it is important to evaluate needed staff skills and to implement training programs to help existing staff improve their skillsets. Another important organizational factor is developing an approach for managing change within the organization to support a culture of continuous improvement.

The remainder of this guide further details the areas illustrated in the figure, with emphasis on those areas that are specific to TAM.

A basic feature of TAM is that it is interdisciplinary, and thus overlaps with a number of other areas, including but not limited to maintenance, project selection and budgeting, performance management, information technology, and risk. To the extent that other resources are available for addressing certain aspects of TAM, the text notes these overlaps and recommends other relevant resources.

The core elements illustrated in Figure 1.2 are further detailed in corresponding chapters of the Guide:

Chapter 1. TAM Basics discusses basic information of importance to any reader who is new to the concepts of transportation asset management.

Chapter 2. TAM Strategy & Planning discusses considerations in linking asset management to agency goals and objectives, and defining performance measures and targets for tracking progress.

Chapter 3. Organization & People describes how to build an organizational structure that supports asset management, and develop processes for change management and training to build an awareness of asset management throughout the organization.

Chapter 4. Maximizing the Performance of Transportation Assets discusses developing life cycle plans that define how best to design, construct, operate, maintain and dispose of assets - and then executing those plans on a day-to-day basis.

Chapter 5. Resource Allocation details the process of making capital and maintenance investment decisions that provide the best long term performance given available resources, considering trade-offs and competing needs between different assets and investment objectives.

Chapter 6. Monitoring & Adjustment addresses topics including tracking asset health, responding to unplanned events, and managing risks to the asset inventory.

Chapter 7. Information & Systems addresses collecting needed asset data, and implementing management systems to support data collection and decision-making.

Intended Audiences: Who Should Use this Guide?

The Guide is an important tool that should be actively used as a reference by the transportation community. The principles and implementation techniques described here are universally applicable to all agencies managing transportation assets. While the target audience is primarily State Departments of Transportation (DOTs), local agencies managing metropolitan, county, or mixed transportation networks will also find it useful and appropriate to their needs.

The Guide is structured so that the reader can use a particular chapter, section, or topic as a source of advice; or use the whole in order to drive a systematic agency-wide implementation of asset management.

For those new to asset management who want to learn more. This Guide is a great starting point for DOT staff new to the field of asset management. Recent college graduates and new DOT employees hired in asset management roles, as well as DOT staff who have transferred to an asset management role from elsewhere in the agency will benefit from the overview of asset management provided in this Guide.

For practitioners. This Guide can help advance asset management practice at an agency. The framework is designed to provide information on all different aspects of asset management, so practitioners can easily access information specific to the challenges they are currently facing. Practitioners can also learn about how peer agencies approach different aspects of asset management through the numerous practice examples throughout the Guide.

For executives. This Guide is intended to raise awareness among senior executives about the wider role TAM plays within the agency and how it can be implemented to improve organizational performance and achieve better outcomes in terms of cost and service to the public. Agency-wide TAM implementation needs to be led by top management using the principles of effective leadership. TAM is an organizational culture and professional discipline that should not be switched on and off with the regular election cycle – it needs continuity and support even as leadership within the organization changes. Implementation needs to transcend administration.

Ways to Use this Guide

The Guide provides an overview of TAM topics and also includes practice examples, how-to guides, checklists, and references.

Basic Overview of TAM

A general overview of TAM is provided below in Section 1.2. This is a great place for people who are new to asset management to learn the basic fundamentals and benefits of TAM before getting into the details in the remaining chapters.

Topical Guidance

Each chapter of Guide provides topical guidance for the practitioners looking to advance a particular aspect of TAM within their agency. While there are certainly cross-cutting topics in TAM that are mentioned in more than one chapter, each chapter is meant to be a stand-alone topic that a practitioner will find useful without having to read the entire Guide.

Practice Examples

There are numerous practical examples in each chapter of the Guide that illustrate how particular aspects of TAM are applied in real world situations. A diverse range of DOTs, MPOs, and international agencies are featured in the practice examples. These illustrate the varying priorities and wide array of challenges facing agencies of all sizes.

Maturity Scale

Each chapter concludes with a summary of the typical level of practice of a generic Department of Transportation for three levels of maturity: emerging, strengthening, and advanced. The maturity examples are meant to provide some context for the concepts discussed within the chapter, and

How-To Guides and Checklists

Each chapter of the Guide features How-To Guides and Checklists.

How-to Guides

How-to Guides provide step-by-step guidance on achieving a specific aspect of TAM. The following How-To Guides are featured in the Guide:

Chapter 2

- Develop an Asset Management Policy (2-9)
- Develop a Risk Register (2-21)
- Prioritize Assets for TAM Advancement (2-31)

Chapter 3

- Recruit Individuals for Asset Management Roles (3-9)
- Establish a TAM Steering Committee (3-23)
- Develop a Communications Plan (3-30)
- Manage Change and Prepare for a System Replacement (3-40)

Chapter 4

- Establish Customer-Based Service Level Targets (4-14)
- Life Cycle Planning for Pavements (4-33)
- Determine What Data Is Needed to Support Life Cycle Management (4-41)

Chapter 5

- Implementing a Multi-Objective Decision Analysis Approach (5-24)

Chapter 6

- Benchmark Performance (6-18)
- Use RACI to Create a Responsibility Assignment (6-49)

TIP Readers of the TAM Guide can reach out to specific agencies for further details on the practices highlighted in the practice examples.

the degree to which an agency adopts them in how they conduct service delivery.

Emerging. The agency is beginning to improve their asset management practices and is emerging to a new way of conducting service delivery. The agency has initiated early steps to advance practices and has a plan for future improvements.

Strengthening. The agency has established many aspects of a functioning asset management system, achieved several important improvements in how it embeds asset management leading practice into the agency, and continues to strengthen its practices to achieve future goals.

Advanced. The agency is a role model among its peer agencies and has fully implemented asset management practices across the organization. TAM has become how the agency does business, with a commitment to continuous improvement over time. The agency is advanced relative to most of its peers.

Tips

Where applicable, helpful Tips are included at the bottom of the page in each chapter. These short and practical items help reinforce the concepts discussed in the chapter. They can also indicate key points to remember when applying the guidance

References

At the end of each individual section of the Guide references are provided for more details on specific topics. Practitioners who want to learn more are encouraged to access these references and take advantage of the various resources that are currently available.

Checklists

Checklists address items that should be place to advance TAM practice in a specific way within an agency. The following Checklists are featured in the Guide:

Chapter 1

- Basic Requirements Checklist (1-12)

Chapter 2

- Ingredients in an Implementation Plan (2-34)

Chapter 3

- TAM Roles (3-10)
- Assessing an Organization's Change Readiness (3-39)

Chapter 4

- Considerations to Support the Successful Implementation of a Life Cycle Approach to Managing Assets (4-44)

Chapter 5

- Preparing a TAM Financial Plan (5-33)

Chapter 6

- Characteristics of Strong Performance Measures for Managing the Condition of Ancillary Assets (6-13)
- Monitoring External Considerations in Risk (6-41)
- Risk Management Process (6-48)

Chapter 7

- Data Items to Standardize for TAM (7-15)
- Asset Data Collection Readiness Checklist (7-26)
- Preparing Data for Sharing, Reporting, and Visualization (7-36)

Section 1.3

TAM Resources

This section provides the information on accessing some of the key references used throughout the guide. Each sub-section briefly describes the reference and notes how to access the document or information.

This section has four parts:

1. **Frameworks and Guidance.** Provides a summary of the existing frameworks and guidance documents, primarily those available internationally.
2. **Legislation and Regulations.** Summarizes the federal legislation related to asset management.
3. **Assessment Tools and Maturity Models.** Summarizes the existing assessment tools and maturity models available.
4. **Communities.** Provides information on communities involved in asset management.

Frameworks and Guidance

There are numerous existing frameworks, models, and guidance documents related to asset management. This Guide is intended to build upon these existing resources and provide updated information where necessary.

International Organization for Standardization (ISO)

ISO

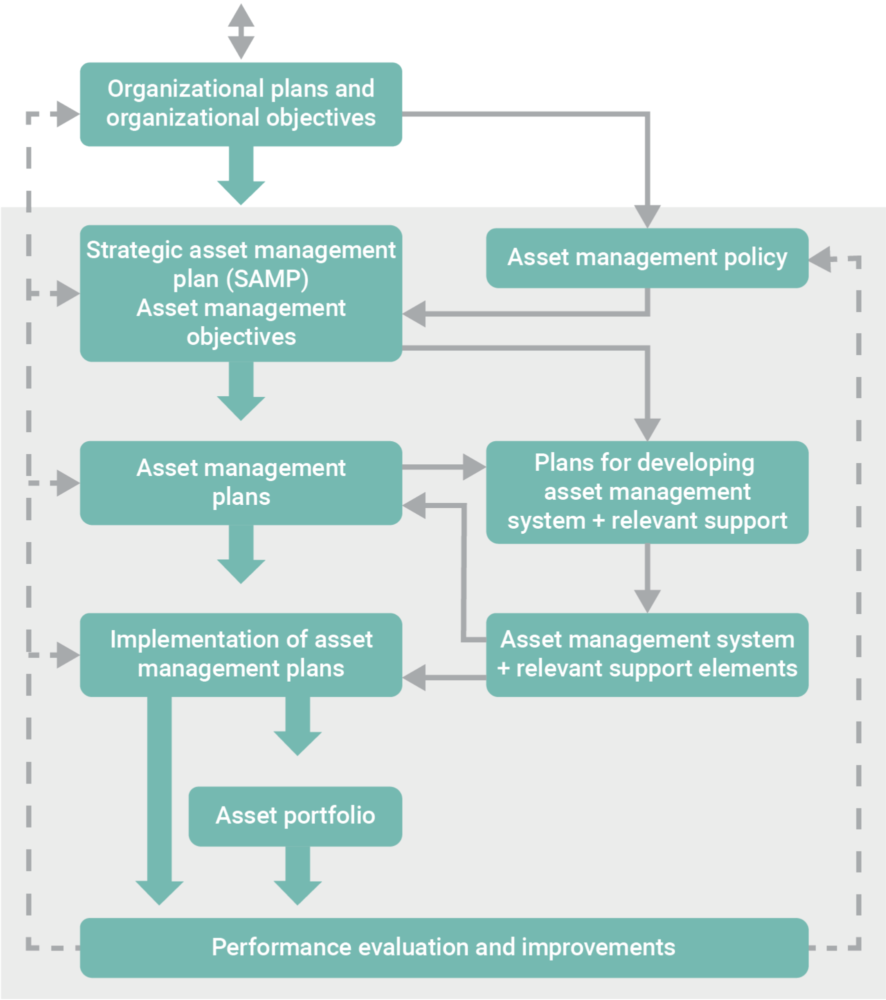
ISO has published a set of standards on asset management. Standard 55000 provides an overview of asset management and asset management systems (i.e. management systems for the management of assets). It also provides the context for ISO 55001 and ISO 55002. International cooperation in the preparation of these standards has identified common practices that can be applied to the broadest range of assets, in the broadest range of organizations, across the broadest range of cultures. The adoption of this International Standard enables an organization to achieve its objectives through the effective and efficient management of its assets. The application of an asset management system provides assurance that those objectives can be achieved consistently and sustainably over time.

Additional standards related to asset management include ISO 55010 which covers guidance on alignment of asset management, finance and accounting; and ISO 55011 which covers guidance on the development of government asset management policy.

For more information, the standard is available to purchase: https://www.iso.org/standard/55088.html

Figure 1.3 Relationship between key elements of an asset management program

The gray box designates the boundary of the asset management system



Source: Adapted from ISO 55000. 2016

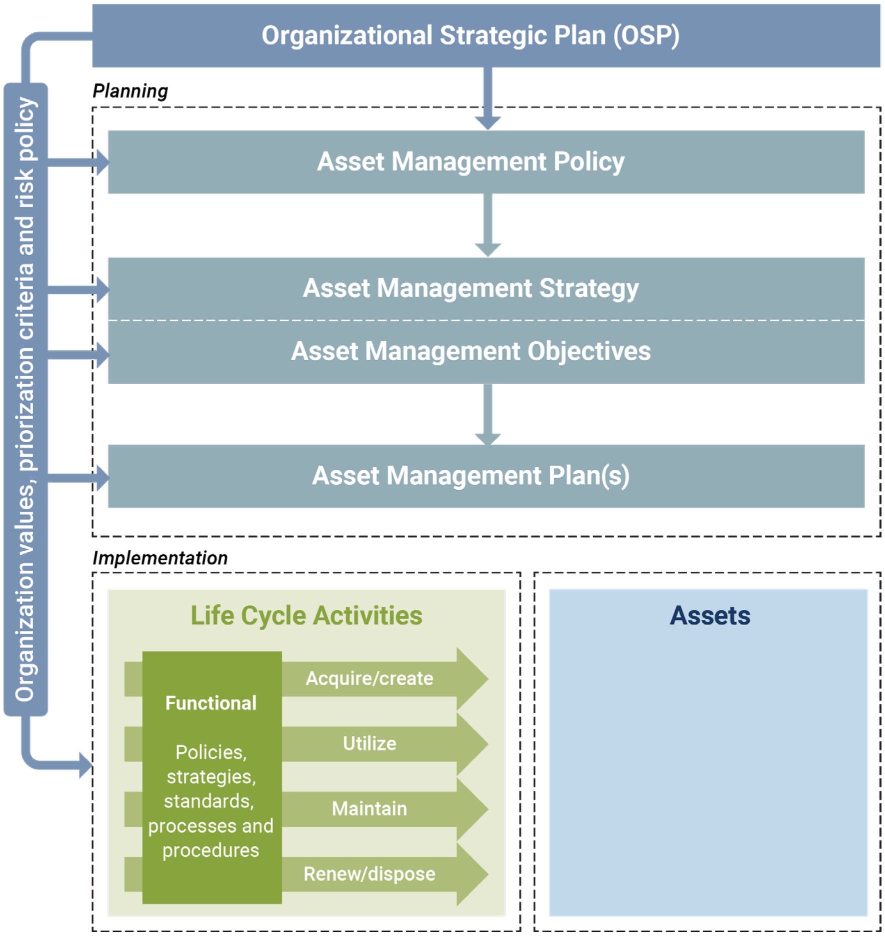
TIP Each asset management framework may emphasize the elements of asset management differently, but they all have the same underlying principles.

Publicly Available Standard (PAS) 55

Prior to the development of ISO 55000, the Publicly Available Standard (PAS) 55 was released by the British Standards Institute. This standard contains terms and definitions; information on asset management policy, strategy, and objectives; discussion on implementing asset management plans; as well as performance assessment and improvement information.

The standard is available to purchase: https://www.iso.org/obp/ui/#iso:std:iso:55000:ed-1:v2:en

Figure 1.4 Planning and implementation elements of an asset management system



Source: Adapted from PAS 55

Institute of Asset Management (IAM)

The IAM publication, *Asset Management – An Anatomy* (2015), provides a basic overview of asset management and its benefits. It also provides a discussion of six asset management subject areas: Strategy and Planning, Asset Management Decision-Making, Life Cycle Delivery, Asset Information, Organization and People, and Risk and Review. These subject areas are reflected in the framework shown in Figure 1.5.

IAM also has information on developing and maintaining a Strategic Asset Management Plan (SAMP). All of their resources can be found on their website: https://theiam.org/

Institute of Public Work Engineering Australasia (IPWEA)

IPWEA has produced the *International Infrastructure Management Manual* (IIMM). This guide provides checklists, process, guidance, and case studies on asset management practice from agencies globally. The manual contains guidance for all infrastructure types and is suitable for agencies of all levels of maturity. The manual is written to align with ISO 55000 with a focus on how to implement asset management concepts.

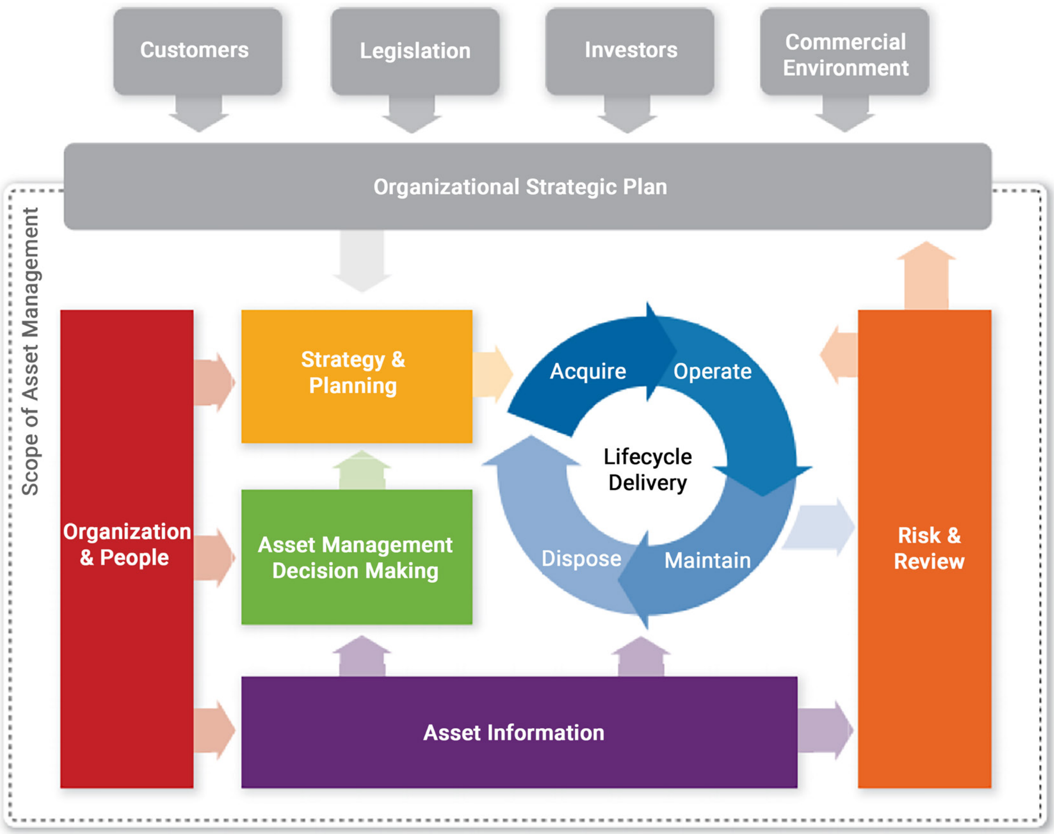
The IIMM must be purchased from the IPWEA online bookshop which can be accessed here: http://www.nams.org.nz/pages/273/international-infrastructure-management-manual-2011-edition.htm

UK Road Liaison Group

The UK Road Liaison Group developed the publication titled *Well-Managed Highway Infrastructure: A Code of Practice*. This code is designed to support and promote the adoption of an integrated asset management approach to highway infrastructure based on the establishment of levels of service through risk based assessment. The code is broken into four sections: Overarching Principles, Highways, Structures, and Lighting. The Code also summarizes 36 recommendations put forward to the Department for Transport to enhance asset management across UK highway networks.

A PDF of this document is available online: http://www.ukroadsliaisongroup.org/en/utilities/document-summary.cfm?docid=4F93BA10-D3B0-4222-827A8C48401B26AC

Figure 1.5 The IAM's Conceptual Asset Management Model



Source: Adapted from IAM Asset Management – An Anatomy. 2015

Legislation and Regulations

The federal government recognizes the importance of asset management practice and requires states to develop transportation asset management plans. Many state governments also have implemented laws related to asset management.

Federal Legislation

The transportation authorization legislation Moving Ahead for Progress in the 21st Century (MAP-21) signed into law in 2012 includes a number of provisions related to asset management and performance management for both highway and transit modes. The requirements established in MAP-21 were continued in the subsequent legislation Fixing America First Act (FAST) signed into law in 2015. For the highway mode MAP-21 defines asset management in the context of transportation and requires that State DOTs develop risk-based transportation asset management plans (TAMPs) for assets on the National Highway System (NHS). The law also includes a number of requirements related to performance management. Regarding transit MAP-21 requires that U.S. transit agencies develop TAMPs that detail asset conditions and include a prioritized list of state of good repair (SGR) investments.

Following passage of MAP-21 and FAST the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) developed rules detailing the TAM requirements for highways and transit, respectively. In 2016 FHWA finalized § 23 Code of Federal Regulations (CFR) Part 515 – Asset Management Plans. FHWA's requirements specify that a TAMP should detail asset inventory, current conditions, and predicted future conditions over a 10-year period, using performance measures detailed in FHWA's performance management regulations. The TAMP should include the following elements:

- Asset Management Objectives
- Asset Management Measures and Targets
- Inventory and Conditions
- Performance Gap Identification
- Life-Cycle Planning
- Risk Management Analysis
- Financial Plan
- Investment Strategies

In 2016, the FTA finalized asset management requirements U.S. transit agencies must follow. These requirements are detailed in §49 CFR Parts 625 and 630. The FTA requirements detail that transit agencies must prepare TAMPs covering a four-year period and including their revenue vehicles, infrastructure, facilities, and equipment (including service vehicles). Agencies must use a decision support tool to help analyze SGR investment needs and develop a prioritized list of needs. Larger agencies (with rail systems and/or 100 or more vehicles in peak revenue service) must include additional materials in their TAMP, such as a TAM/SGR policy, TAM implementation strategy, evaluation plan, and identification of resources required to implement the plan.

TIP **While regulations do exist, TAM benefits are best achieved when not implemented as a box checking activity.**

Assessment Tools and Maturity Models

Assessing asset management maturity helps establish goals and encourages improvement. This section provides information on existing assessment tools and maturity models agencies can use as resources.

TAM Gap Analysis Tool

This Excel-based gap analysis tool was developed under National Cooperative Highway Research Program (NCHRP) Project 08-90 and builds on the gap analysis tool introduced in the *AASHTO Transportation Asset Management Guide – A Focus on Implementation*. The tool helps agencies identify and prioritize needed enhancements to their asset management programs. The tool is available on the AASHTO TAM Portal: https://www.tam-portal.com/resource/aashto-transportation-asset-management-gap-analysis-tool-users-guide/

IAM Maturity Scale and Guidance

The IAM Maturity Scale and Guidance document provides a generic maturity scale for agencies looking to assess their current asset management practice and determine ways to grow and mature. This guidance is available for purchase here: https://theiam.org/knowledge/Knowledge-Base/asset-management-maturity-scale-and-guidance/

Data Gap Assessment Tool

To assess data and information maturity, agencies can use *NCHRP Report 814, Data to Support Transportation Agency Business Needs: A Self-Assessment Guide*. This report provides steps to prepare for the assessment, conduct the assessment, and improve and monitor the agency's data and information maturity over time. The assessment approach presented is flexible and scalable to many different agency needs. The Guide helps agencies determine if they have the right data, if their data is good enough, if they are getting full value from their data, and what they need to do to improve.

TPM Assessment Tool

The self-assessment available on the Transportation Performance Management (TPM) Toolbox (www.tpmtools.org) is available to agencies looking to assess their level of performance management maturity. Three different assessment options are available: a quick, 2-minute assessment, a standard assessment, and an assessment by component of the TPM framework presented in the TPM Guidebook.

TIP **Repeated or frequent maturity assessments can be useful for mid course corrections; however they should be spaced out enough to avoid over burdening the department or agency.**

Communities

There are numerous opportunities available for practitioners to interact with people from peer agencies. The following committees and groups provide a way for agencies to share ideas, overcome challenges, and advance asset management practice.

American Association of State Highway and Transportation Officials (AASHTO)

AASHTO is a nonprofit, nonpartisan association representing highway and transportation departments in the 50 States, the District of Columbia, and Puerto Rico. It represents all transportation modes including: air, highways, public transportation, active transportation, rail, and water. It aims to foster the development, operation, and maintenance of an integrated national transportation system. AASHTO is an international leader in setting technical standards for all phases of highway system development.
https://www.transportation.org

The AASHTO Committee on Performance-Based Management (CPBM) is dedicated to providing State DOTs the expertise and resources to support performance-based management and to create a results-driven environment to maximize the performance of both transportation systems and organizations. The committee is focused on Organizational Management, Systems Performance, and Federal Policy, Regulations and Programs.

The CPBM's Subcommittee on Asset Management was created to help improve the State-of-the-practice of asset management in State DOTs. The Subcommittee works to help States optimize resources with performance-based goals and measures for operation, preservation, and improvement of their transportation systems.Transportation Research Board (TRB)

TRB provides innovative, research-based solutions to improve transportation. TRB is a program unit of the National Academy of Sciences, Engineering and Medicine, a non-profit organization that provides independent, objective, and interdisciplinary solutions. TRB manages transportation research by producing publications and online resources. It convenes experts that help to develop solutions to problems and issues facing transportation professionals, and provides advice through its policy studies that tackle complex and often controversial issues of national significance.
http://www.trb.org/Main/Home.aspx

TRB Committee on Transportation Asset Management. The Committee seeks to advance the State of the art and State of the practice in asset management. Asset management is a process to strategically manage the transportation system in a cost-effective and efficient manner. Asset management by its nature is a collaborative process, and the Asset Management Committee works with other TRB Committees across all modes, with the AASHTO Asset Management Subcommittee, and other partners.

TIP **Most of these TAM communities have websites that house a wealth of resources and information, including training opportunities.**

Federal Highway Administration (FHWA)

FHWA is an agency within the U.S. Department of Transportation that supports State and local governments in the design, construction, and maintenance of the Nation's highway system, and various Federal and tribal owned lands. Through financial and technical assistance to State and local governments, the FHWA is responsible for ensuring that America's roads and highways continue to be among the safest and most technologically sound in the world. https://www.fhwa.dot.gov

FHWA TAM Expert Task Group (ETG). TAM ETG was formed as a forum to discuss changes in the way highway agencies are managing assets. The structure and membership of the TAM ETG were intentionally designed to ensure interaction with key AASHTO and TRB committees. Among its objectives, the TAM ETG aims to identify strategies for advancing asset management practice and influencing change within State DOTs and partnering with transportation agencies.

IAM

The IAM is the international professional body for asset management professionals. The IAM develops asset management knowledge and best practice, and generates awareness of the benefits of the asset management discipline for the individual, organizations and wider society. Established in 1994, the IAM has over 22,000 members in 158 different countries. https://theiam.org

IAM US Patron Group. The Patrons of the IAM are a special group of Corporate Members who have committed to a high level of activity and engagement with the Institute, and on that basis, have been invited to become a Patron. The Patrons include leading asset managers, who, in exchange for significant support to the Institute, have great influence not only on the development of the IAM itself but also on the development on the discipline.

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Section 2.1
Developing a TAM Strategy

Section 2.2
TAM Integration

Section 2.3
TAM Assessment and Advancement

Section 2.4
Developing a Transportation Asset Management Plan (TAMP)

Chapter 2
TAM Strategy and Planning

Section 2.1

Developing a TAM Strategy provides information on creating a TAM policy and aligning it with other strategic plans within the agency.

Section 2.2

TAM Integration explains the importance of integrating TAM within planning and programming, risk management, and information management.

Section 2.3

TAM Assessment and Advancement offers guidance on assessing current TAM practice and prioritizing areas for improvements.

Section 2.4

Developing a Transportation Asset Management Plan (TAMP) introduces the basic elements of a TAMP and describes ways agencies might go beyond the basic requirements.

Chapter 2
TAM Strategy and Planning

Developing TAM strategies is an agency-wide activity undertaken to ensure that the agency delivers on its vision, mission and defined asset management objectives and targets. A TAM strategy is the big-picture outlook needed to integrate TAM with existing processes and make ongoing improvements once TAM is underway. While practices in TAM strategy development vary across agencies, a strategy will generally establish agency specific TAM principles, connect to agency strategic goals, and provide a framework for how TAM will be carried out.

Key Terms

Asset Class
A type of asset (e.g. pavement, bridge, sign, signal, etc.).

Goals
Broad statements articulating a desired end state that provide strategic direction for an agency. (*TPM Guidebook*)

Information Management
The processes and framework for acquiring, distributing, and storing information at an agency.

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

Objectives
Specific, measurable statements that support achievement of a goal. (*TPM Guidebook*)

Performance Management
A process that provides accountability and feedback to ensure that goals are met in an efficient and effective manner.

Planning
The use of agency goals and objectives to drive development of strategies and priorities in the long-range transportation plan and other plans and processes. (*TPM Guidebook*)

TAM Policy
Defines the approach the agency will take to achieve the goals and objectives set forth in the strategic plan.

Principles
From a TAM perspective, fundamental ideas that serve as a foundation for making decisions to better address infrastructure needs.

Programming
The use of strategies and priorities to guide the allocation of resources to projects that are selected to achieve goals, objectives, and targets. (*TPM Guidebook*)

Risk Management
The processes and framework for managing potential risks, including identifying, analyzing, evaluating, and addressing the risks to assets and system performance. (23.C.F.R 515.5)

Strategic Plan
Sets a vision for the future of the agency and defines the goals and objectives to achieve that vision.

TAMP
Transportation Asset Management Plan

Targets
Quantifiable levels of performance the agency wants to achieve within a specific time frame. (*TPM Guidebook*)

Section 2.1

Developing a TAM Strategy

TAM strategies and plans should be integrated within the agency's overall vision and strategy documents and other related plans. A stand-alone TAM policy can also be used to establish leadership support, define principles and communicate the purpose of TAM.

This section has two parts:

1. **Integrating TAM Within Agency Strategic Plans and Policies.** It is important to include TAM as a part of agency-wide plans and policies in order to establish the role of TAM within the agency.

2. **Creating a TAM Policy.** This section outlines the key aspects of a TAM policy and how to develop it.

Integrating TAM Within Agency Strategic Plans and Policies

Integrating TAM within existing strategic documents is key to ensuring TAM is established and sustained.

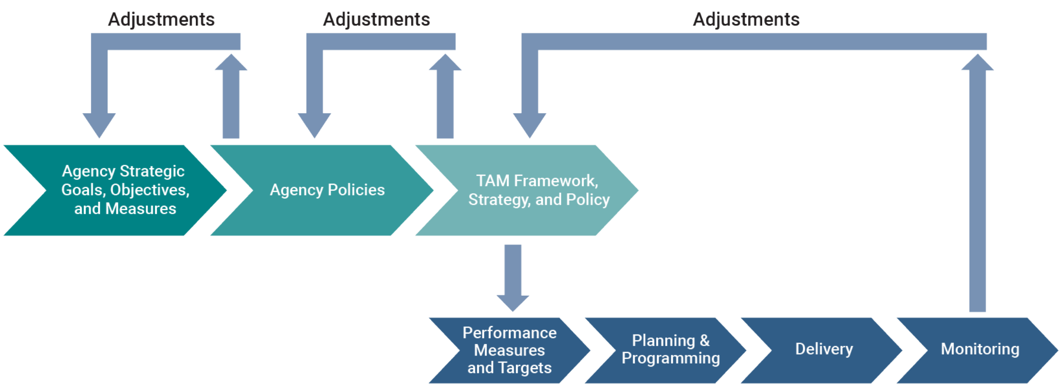
TAM is not a stand-alone practice that is only applicable to select areas of a DOT. Ideally, TAM principles and practices should be integrated within an agency's vision, mission and strategy documents (see Figure 2.1). TAM promotes accountability, preservation, data-driven decision-making and the optimization of resources; all of these are broader strategic goals often outlined in plans and policies other than a TAMP. Aligning TAM with the agency's strategic documents helps ensure an agency's vision is all encompassing and cohesive.

These documents include:

- Agency-wide strategic plan and/or business plan (including long-range plans)
- Agency-wide financial plan
- State long-range plan
- Other performance plans (safety, mobility, freight, etc.)

In addition, some agencies may choose to adopt a TAM policy with principles that the agency will follow. A TAM policy can be used to communicate the purpose of TAM and build understanding and support for TAM within the agency. It can also help to sustain a TAM approach through leadership changes. See the next section for further information on creating a TAM policy.

Figure 2.1 Aligning Policies and Plans



Practice Example
Integrating TAM

Michigan DOT

MDOT's 2017 strategic plan has seven strategic areas of focus. A key focus area is System Focus, which aims to provide cost-effective, integrated and sustainable transportation solutions. The first strategy under this focus is to "apply asset management principles to prioritize and implement the most cost-effective transportation investment strategies." This connection between MDOT's strategic plan and their TAM program communicates the importance of asset management in how the agency conducts business. It gives TAM a seat at the agency-wide strategic plan monitoring sessions and allows for the resources needed to carry out TAM activities.

Source: Michigan DOT. 2017. *MDOT Strategic Plan.* https://www.michigan.gov/documents/mdot/MDOT_2017_StrategicPlan_553573_7.pdf

TIP Line of Sight' is a concept that describes alignment of an agency s asset management practice to its strategic goals and business objectives.

Creating a TAM Policy

A TAM policy describes the adoption of asset management principles for managing infrastructure. It defines the intent of the TAM program and can include how TAM will be carried out in the agency. Leadership direction on the policy helps achieve buy-in throughout the agency, making it easier to ensure it connects to and aligns with other strategic documents.

A TAM policy can be the first place an agency communicates the strategy of their TAM program. It can be thought of as a contract between the agency and its customers, partners and stakeholders that defines how TAM fits within the agency's decision making process.

Some elements of a TAM Policy can be included within a TAMP (TAM Objectives, Scope of TAM, connection of TAM to other planning initiatives, and TAM roles). However, a separate TAM Policy may provide those responsible for TAM within an organization the ability to challenge existing processes and approaches. A concise TAM Policy defines the principles that guide the decisions made during TAMP development and implementation.

A TAM Policy can outline the types of assets considered for management and identify where in the cycle of DOT work activities to emphasize asset management practices. It can also establish the high-priority initiatives on which the agency will focus their efforts. A TAM policy starts to set boundaries and clarify the intent of asset management.

A TAM policy may include:

- Definitions of services provided to customers and distinctions between service levels
- Approaches for managing assets from a whole life perspective
- Decision-making standards, based on the triple bottom line (economic, environmental, and social)
- Consideration of risk
- Approach for making transparent, data-driven decisions

For further details on developing a TAM Policy, see the how-to guide in this chapter.

TAM Goals, Objectives, Strategies

TAM goals and objectives support and communicate the policy and align with the broader agency vision, mission, goals and strategies. Goals and objectives may cover transportation system performance and desired outcomes, as well as agency decision-making approaches and practices. Some agencies have goals and objectives, while some have only goals and others have only objectives. Regardless of the terminology that is used, it is important that agencies set a vision and establish a direction to move towards. The Oklahoma DOT practice example highlights their TAM objectives.

Agencies should include a clear statement of TAM principles – either within the agency's strategic documents or as a stand-alone policy. They should also seek opportunities to strengthen the integration of TAM within the agency's strategic planning efforts.

Practice Example
TAM Objectives

Oklahoma DOT

The Oklahoma DOT identified the following TAM objectives to help guide their asset management program:

- Maintain (improve) the condition of the state's bridges and roadways
- Reduce risk associated with asset performance
- Make better data driven decisions about assets
- Reduce costs and improve efficiency, including effectively delivering projects that support asset management
- Increase internal and external communications and transparency
- Improve customer service
- Improve safety on the state's transportation system
- Enhance mobility of people and goods

TIP **A TAM Policy can be a sign of leadership commitment to implementing asset management. A good policy is clear, concise, and easy to interpret.**

Ingredients for Success in Creating a TAM Policy

The following are some of the key ingredients that make a TAM policy successful.

Leadership Support

Leadership support and direction in the effort to create a TAM policy is important. Effective leadership ensures and maintains a connection across the various types of goals. A typical transportation agency has a lot of moving parts and multiple, sometimes conflicting, priorities. The nature of TAM and its success in meeting TAM goals involves actions that cut across individual business units. Leadership is a critical ingredient in creating positive change and maintaining processes across business units. See section 3.1 for more information on leadership.

Internal and External Stakeholder Engagement and Support

Involving groups and people who want a voice in the TAM program's success, whether external partners or stakeholders or internal business units, is important for creating policies that will have a positive impact and are sustainable. See section 3.2 for more on stakeholder engagement.

Consider Implementation

There may be multiple ways to accomplish policy objectives, so the policy should be simple and flexible rather than complex and rigid.

Link to Performance Management

Performance management is an underlying component of good asset management. Policies should consider the ability to define performance measures, collect data and measure performance. They should also consider the cycle of setting objectives, monitoring performance and making adjustments. See section 2.2 for more on TAM performance and monitoring.

Practice Example TAM Policy

Amtrak

Amtrak Engineering's Asset Management policy identifies guiding principles that the agency intends to use in managing the infrastructure it owns and maintains. Specifically, the policy focuses on developing asset management capability and implementing the TAMP. The policy begins with a purpose statement that defines asset management, and then lays out seven principles (or standards) to guide asset management practice. The principles highlight ownership, transparency, risk management, life cycle costs and information systems standards for Amtrak's asset management practice. In addition, the policy also identifies responsibilities and leadership commitment, calling out specific positions in the agency and their role in delivering the asset management plan. The policy is included as a section in their asset management plan and is signed by the President and CEO, EVP Chief Operating Officer, and VP Chief Engineer.

TAM Principles

FHWA Principles of Asset Management

FHWA has defined a number of basic principles for asset management as listed below. All of these ideas work together to help an agency make decisions to better address their infrastructure needs. Asset management should be:

Policy driven. Decisions reflect policy goals and objectives that define desired system condition and service levels.

Performance based. Performance information is used to establish target levels, to allocate funding, and to monitor progress.

Risk based. Risk management is used to identify, analyze, evaluate and address the risks to assets and system performance.

Option oriented. Comprehensive choices and trade-offs are examined at each level of decision making.

Data driven. Management systems and tools that utilize quality data are used to support decisions.

Transparent. There are clear criteria for making decisions.

Practice Examples

Adopting Asset Management Principles • Seattle DOT

Seattle is one of the fastest growing cities in the U.S. and the demands on the transportation system have grown dramatically. Meanwhile, the system is aging. Seattle DOT (SDOT) needed to find a way to balance infrastructure expansion, preservation, and maintenance by aligning its Asset Management practices with its service delivery strategies. All of this had to occur within the limits of available resources and ensure that SDOT strategically managed the transportation system for years to come. SDOT's Asset Management initiative provides a long-term vision of how SDOT intends to accomplish its mission. In 2007, the SDOT began implementation of a strategic and systematic process that guides decisions about construction, maintenance, and operation of SDOT infrastructure. The SDOT identified and adopted the following three key principles of asset management:

- Build, preserve, and operate transportation infrastructure services more cost effectively with improved asset performance;
- Deliver to customers the best value for public tax dollars spent; and
- Enhance the credibility and accountability of SDOT to the Mayor and City Council

These principles were intended to identify the outcome of a fully implemented asset management program at SDOT. They are supported by a longer list of asset management principles (https://www.seattle.gov/transportation/about-sdot/asset-management) and an Asset management Policy that identify the areas of focus. The Policy highlights the steps SDOT intends to take recognizing that achieving the key principles is a long-term effort achieved through continuous improvement.

Creating an Asset Management Policy • Colorado DOT

In 2015, the Colorado Department of Transportation (CDOT) updated Policy Directive 14 (PD 14.0) "Policy Guiding Statewide Plan Development" to reinforce the importance of TAM in the transportation budget allocation process. It includes the following objectives:

- Infrastructure Condition – Preserve the transportation infrastructure condition to ensure safety and mobility at a least life cycle cost
- Maintenance – Annually maintain CDOT's roadways and facilities to minimize the need for replacement and rehabilitation

Embedded in this policy are target-setting requirements that the Transportation Commission requested. A performance tracking mechanism is tied to this policy directive. This performance management focus is reinforced annually in a PD14 workshop hosted by the Transportation Commission where the most recent performance results are presented.

CDOT

2017 Policy Directive 14 Scorecard

Infrastructure Condition
Highways

PD 14.0 Objectives	2017				2016				Dedicated Funding Sources[1]	Notes
	Budget	Target	Results	Target Met?	Budget	Target	Results	Target Met?		
Achieve 80% High/Moderate Drivability Life for Interstates based on condition standards and treatments set for traffic volume categories	$252.1 million	80%	88%		$235.9 million	80%	94%		Surface Treatment Program RAMP Funding	Although targets were met in 2017, given the current planning budgets, it is anticipated that targets for pavement condition will not be met beginning next year, and will continue to remain below the target through 2027. In 2027 it is anticipated that only 44% of the state highway system will have high or moderate Drivability Life. $107 million per year is needed annually beyond FY 2022 to achieve the target by 2027. Staff will work to improve/tighten the link between pavement maintenance and pavement model recommendation, and evaluate the effect of pavement preventive maintenance on DL to identify strategies. Additionally, continuing work to align current DL metric with new FHWA metrics of Good/Fair/Poor pavement condition of the NHS System.
Achieve 80% High/Moderate Drivability Life for NHS, excluding Interstates, based on condition standards and treatments set for traffic volume categories		80%	84%			80%	85%			
Achieve 80% High/Moderate Drivability Life for the state highway system based on condition standards and treatments set for traffic volume categories		80%	80%			80%	80%			

Infrastructure Condition
Bridges

PD 14.0 Objectives	2017				2016				Dedicated Funding Sources[1]	Notes
	Budget	Target	Results	Target Met?	Budget	Target	Results	Target Met?		
Maintain the percent of NHS total bridge deck area that is not structurally deficient at or above 90%	$167.4 million	90.0%	95.8%		$164.1 million	90.0%	95.5%		Colorado Bridge Enterprise On-System Bridge RAMP Funding	A structurally deficient bridge is typically one where corrosion or deterioration has resulted in a portion of the bridge being in poor condition; for example, where water leaking through an expansion joint has caused the end of a steel girder to rust. Currently exceeding target and will continue to exceed target through 2027. $37.3 million is needed in preventative maintenance to continue meeting the current target and expecting 96% not poor condition in 2017. However, the bridge program has 7 metrics geared towards mitigation of risks (below), and none of those are not achieving their target. For the seven risk mitigation metrics not achieving their target, staff are working to identify additional strategies that can be implemented with no additional funding. Current strategies include identifying bridges that can easily be repaired or remedied with the most cost-effective treatment.
Maintain the percent of state highway total bridge deck area that is not structurally deficient at or above 90%		90.0%	95.4%			90.0%	95.1%			
Percentage of CDOT-owned bridges over waterways that are scour critical.		5.0%	6.5%			5.0%	6.4%			Scour critical bridges are at risk of failure during a storm event of sufficient size.
Percentage of bridge crossings over Interstates, U.S. routes and Colorado state highways with a vertical clearance less than the statutory maximum vehicle height of 14 feet-6 inches		1.0%	2.4%			0.4%	1.7%			A bridge with a vertical clearance of less than 14'-6"—statutory maximum vehicle height—has a high risk of being hit by a tall load or legal load. Changed target last year (2017 Target = 1.0%; 2016 Target = 0.4%) due the number of bridges with vertical clearance issues is greater than projected.
Percentage of bridge crossings over Interstates, U.S. Routes and Colorado state highways with a vertical clearance less than the minimum design requirement of 16 feet-6 inches		18.0%	21.8%			4.8%	19.8%			16'-6" is the minimum clearance used when designing new bridges over a roadway. A bridge with a vertical clearance less than 16'-6" but greater than or equal to 14'-6" has a medium to high risk of being hit by a tall load. Changed target last year (2017 Target = 18.0%; 2016 Target = 4.8%) due the number of bridges with vertical clearance issues is greater than projected.

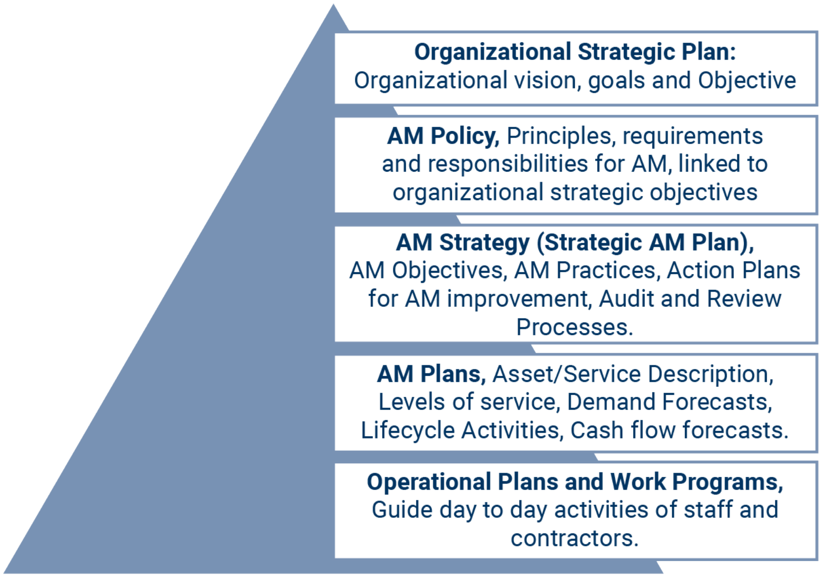
[1] Additional flexible funding sources with a wide range of eligibility could be used to address multiple objectives. Examples include RPP, STP-M, CMAQ, and TAP

Source: Colorado DOT Scorecard. 2017

Practice Example
Strategic Asset Management System

ISO 55000

ISO 55000 adopts the concept of an Asset Management System, as the figure at right illustrates, which typically consists of several components:



Asset Management System Components

- An organizational strategic plan sets the overall context
- An asset management policy establishes the principles on which the agency makes decisions associated with the management of and investment in infrastructure. It seeks to link the organizational goals and objectives to the principles for management of the infrastructure portfolio.
- The Asset Management Strategy, (sometimes termed the Strategic Asset Management Plan or SAMP) establishes how the agency overall will implement asset management and implement the AM Policy. It articulates how management processes will function in managing infrastructure and delivering services, as well as how the agency will continuously improve their asset management practices over time.
- Asset management plans developed for individual asset classes (pavements, bridges, ancillary assets) are focused on their individual portfolios. However, they align with the overall agency strategy and are customized to the level of management required.
- Operational plans and work programs guide routine activities and have a line of sight to overall agency goals in this structure.

Within the ISO structure, the TAM framework includes these components but each component may vary in scope. For example, the SAMP may require all asset classes to forecast demand, establish service levels and have performance indicators, but compliant sub-asset management plans may have different levels of complexity. A bridge asset management plan may be more robust than one for network culverts. The agency can select the scope and structure appropriate for each aspect within the portfolio.

Source: IPWEA. 2015. International Infrastructure Management Manual (IIMM). https://www.ipwea.org/publications/ipweabookshop/iimm

How-to

Develop an Asset Management Policy

A TAM policy helps to formalize the asset management practices that an agency uses on a daily basis. It helps ensure that the goals, objectives, and strategies for TAM are unified and pursued consistently across the agency. This How-To Guide provides eight steps for developing a TAM policy.

1. Identify who will issue the primary TAM policy and who is responsible for developing the policy

As a first step, it is important to determine the roles and responsibilities for policy development. TAM policies can be developed and issued from many different groups within an agency. Often agency leadership is involved and executive staff work with planning, engineering, or another group to develop the primary policy. The policy can be issued by the agency CEO, a transportation commission, or even the state legislative body. The level of responsibility will also assist in assigning the breadth of accountability for implementation of the policy within the agency.

2. Clarify what the policy intends to achieve

Determine the objectives of the policy. Is the purpose of the policy to:

- Communicate the importance of TAM and the scope of the program?
- Ensure the TAM program is sustained through leadership changes at the agency?
- Bring different parts of the organization together?
- Other objectives?

3. Decide what the policy should include

TAM policies can include:

- Material that communicates the definition of TAM
- TAM principles (see page 2-6)
- Scope of TAM within the agency (e.g. assets included and decisions impacted)
- A vision for where the agency wants to go in the future. That vision could be to maintain all assets in a state of good repair, for example
- How TAM will be managed within the agency or region. Consider who take the lead and who will be involved. See discussion of roles and responsibilities in Section 3.1
- Elements of performance management (i.e. specific performance measures, targets, who determine the targets, who monitors, etc.)

In addition, agencies should discuss the time horizon over which the policy will govern.

Developing a TAM Policy

1. Identify who will issue the TAM policy
2. Clarify what the policy intends to achieve
3. Decide What the Policy Should Include
4. Review Peers' TAM Policies
5. Consult Stakeholders
6. Draft the policy and share with stakeholders
7. Produce the final policy and communicate it
8. Review and update the policy

How-to

Develop an Asset Management Policy

4. Review existing TAM policies at peer agencies

Agencies considering developing their first TAM policy do not have to start from scratch. There are existing policies that outline asset management principles from which agencies can draw when developing their own. When reviewing existing policies, agencies can look for elements to adapt to their specific needs and fill in any gaps with other principles they seek to prioritize in their asset management programs. Example TAM policies may be found on the AASHTO TAM Portal. http:// www.tam-portal.com.

5. Consult stakeholders on the content of the policy

As an agency develops its TAM policy, it is important to consult internal and external stakeholders on its general contents. Different types of stakeholders may need to be involved using different methods, in order to appropriately obtain their input.

6. Draft the policy and share with stakeholders

Once a draft of the policy is available, it is important to circulate it to stakeholders to ensure the policy appropriately reflects all previous discussions and decisions.

7. Produce the final policy and communicate it across the agency

When the policy is finalized, staff should ensure that it is communicated across the agency. The TAM policy should be on the agenda at key meetings throughout the agency to promote awareness. Also, any needed changes to business processes should be implemented to ensure they support the policy.

8. Review and update the policy

Over time the policy should be reviewed and updated if necessary. The need to revisit the process may occur as implementation of the policy matures, or due to changes in roles and responsibilities within an organization, creating a desire to reaffirm a commitment to TAM through this document.

Developing a TAM Policy

1. Identify who will issue the TAM policy
2. Clarify what the policy intends to achieve
3. Decide What the Policy Should Include
4. Review Peers' TAM Policies
5. Consult Stakeholders
6. Draft the policy and share with stakeholders
7. Produce the final policy and communicate it
8. Review and update the policy

Section 2.2

TAM Integration

An integrated view of TAM is critical to its advancement within an agency. Integration ensures TAM is linked to other existing business processes within the agency. Integrated planning considers the life cycle of an asset comprising the “cradle-to-grave” approach. Understanding each phase of the life cycle requires coordination between planning, design and operations teams.

This section has four parts:

1. **Planning and Programming.** Decisions made during the planning and programming process establish the strategic framework for TAM choices during the delivery and implementation process.
2. **Performance Management.** Within all TAM programs, the use of performance management is critical to align investment decisions with organizational objectives.
3. **Risk Management.** Risk management is integrated with TAM processes at the strategic level. Risk can also be considered at the asset level to understand the impact of asset failure on the wider system.
4. **Information Management.** How agencies manage data and information, and how these are used, are important considerations in TAM.

Planning and Programming

Linking and aligning asset management with planning and programming activities helps strengthen an agency's delivery of projects. Planning and programming processes set strategic direction and resource allocation practices; TAM helps set priorities and encourages data-driven, performance-based decision-making.

Planning is the process of setting strategic direction through goals and objectives, then performing analysis to identify trends, strategies, and long-term investment priorities. Planning answers the questions of where to go and how to get there. Programming involves allocating resources in order to determine a program of projects the agency will pursue. Planning and programming are central to the work of any transportation agency. Integrating TAM into the planning and programming process will only strengthen and sustain the practices involved in both areas.

Developing the Long-Range Transportation Plan (LRTP) and the Statewide Transportation Improvement Plan (STIP) are two planning activities where the integration of TAM is especially relevant.

TAM principles, data and tools can help shape the LRTP and STIP by:

- Linking agency resource allocation to policy objectives.
- Defining the performance targets to be achieved.
- Identifying strategic investment choices and evaluating and analyzing tradeoffs among them at the appropriate stages.
- Providing the information and analyses to facilitate the appropriate resource allocation decisions that follow good TAM practice.

Integrating TAM approaches with planning and programming goes beyond informing and shaping the activities. Communication and coordination between activities and the people involved in them is important as well. Both planning and TAM require an understanding of the life cycle of an asset. This requires coordination with operations teams to communicate how decisions impact the expected useful life of the asset. Operations teams also need to be aware of the asset management planning horizon, performance measures and targets. These teams need to ensure the capital plan has been accounted for in the maintenance and operational plans. In addition, since planning is a network-level endeavor, teams managing each of the different asset types need to communicate with one another and coordinate with planning.

The following are some key questions to ask when considering the integration of TAM with planning and programming.

- Is the cost of maintenance and operations taken into account in the decision-making process to select capital projects?
- Are there mechanisms to directly evaluate tradeoffs between capital investment and operations and maintenance implications within the planning process?
- Are the needs and implications associated with connected and autonomous vehicles considered in the asset management plan?

Practice Example
Aligning a TAMP to Broader Planning Initiatives

Montana Department of Transportation (MDT)

When developing their 2018 TAMP MDT aligned their pavement performance targets and goals to those within their planning document TranPlan 21 (now TranPlanMT).

TranPlanMT defines MDT's policy direction for operating, preserving, and improving Montana's transportation system over a 20-year period. It serves as the guiding document for MDT decisions, especially those related to investing Montana's limited transportation funds.

This type of alignment can help illustrate a link from policy objectives to investment strategies and resource allocation.

Sources:

Montana DOT. 2018. *MDT TAMP.* https://www.tamptemplate.org/tamp/030_montanadt/

Montana DOT. *TranPlanMt.* https://www.mdt.mt.gov/tranplan/

TIP **TAM practice is most effective when linked to planning and programming activities; this is one way to ensure that TAM principles are implemented into agency decision making.**

- Are future risks such as climate change fully integrated into the capital planning process (rehabilitations, renewal, service level upgrades, etc.)? Is scenario planning used to assess the risk effects of system wide external changes?

The FHWA Asset Management Financial Report Series, *Report 4 Integrating Financial Plans into the Planning, Programming, and Budgeting Processes* describes the importance of integrating planning, programming, and budgeting with asset management.

The relative timeframes of various planning and programming activities is shown in figure 2.2.

Figure 2.2 The Relative Timeframes Between Plans

Long range plans, asset management plans, TIPs, and state budgets should be aligned.

20-Year Long Range Transportation Plan

Provides Goals, Vision, Long-Term Context

10-Year Asset Management Plan	**10-Year Asset Management Plan**
• Specific asset condition targets • System resiliency strategies • Lifecycle investment strategies • Recommended asset program allocations	• Specific asset condition targets • System resiliency strategies • Lifecycle investment strategies • Recommended asset program allocations

4-Year STIP/TIP	4-Year STIP/TIP	4-Year STIP/TIP	4-Year STIP/TIP	4-Year STIP/TIP
Contains projects to execute the TAMP and LRTP	Contains projects to execute the TAMP and LRTP	Contains projects to execute the TAMP and LRTP	Contains projects to execute the TAMP and LRTP	Contains projects to execute the TAMP and LRTP

2-Year State Budget	2-Year State Budget	2-Year State Budget	2-Year State Budget	2-Year State Budget	2-Year State Budget	2-Year State Budget	2-Year State Budget	2-Year State Budget	2-Year State Budget

Source: FHWA. 2017. https://www.fhwa.dot.gov/asset/plans/financial/hif16001.pdf

TIP Involving internal and external stakeholders in the TAM process early can encourage or enhance their buy in when the time comes to make important decisions.

Performance Management

Asset management utilizes performance management to set objectives, define measures, establish targets, and monitor results. Transportation Performance Management (TPM) relies on the TAM principles and process to help achieve the agency's broader goals and objectives.

Relationship to Federal TPM Activities

The MAP-21 Act (2012) established a performance-based program intended to focus Federal Aid highway program and public transportation system (e.g., bus, light rail, and ferry) investments on national transportation goals. It was also intended to increase accountability and transparency in the use of federal transportation funds, as well as improve project decision-making through the strategic use of system performance information. The performance-based provisions of MAP-21 were retained in the FAST Act in 2015.

TPM is defined by FHWA as a strategic approach to making investment and policy decisions to achieve national performance goals using system information in accordance with rules established by the Department of Transportation (see Figure 2.3). The FHWA recognizes asset management as the application of TPM to manage the condition of infrastructure assets needed to provide for mobility and safety in the nation's transportation system. In short, the FHWA refers to asset management as the engine driving infrastructure performance.

Figure 2.3. FHWA's Strategic Approach to TPM

Source: FHWA TPM Homepage. 2019. https://www.fhwa.dot.gov/tpm/

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.

TPM Regulations

The TPM provisions for highways included in federal law are implemented in accordance with rulemakings organized around the following six elements:

- **National goals –** focusing the Federal Aid highway program on the seven areas listed below:
    - Congestion reduction
    - System reliability
    - Environmental sustainability
    - Freight and economic vitality
    - Infrastructure condition
    - Reduced project delivery delays
    - Safety
- **Measures –** assessing performance or condition in carrying out the TPM-based Federal Aid highway program
- **Targets –** funding recipients are required to document future performance expectations under a fiscally-constrained environment
- **Plans –** identifying strategies and investments for addressing performance needs
- **Reports –** documenting progress toward target achievement and investment effectiveness
- **Accountability and transparency –** requiring federal funding recipients to achieve or make significant progress toward targets

TPM Relationship with TAM

There is a close relationship between TPM and TAM, since both consider asset and system performance, risks and available resources to achieve desired objectives over time. Both rely on a strategic approach, using data to make investment and policy decisions in order to achieve performance objectives. Internationally, there is less distinction between asset management and performance management, with the IAM defining asset management as encompassing the "balancing of cost, opportunities and risks against the desired performance of assets to achieve the organizational objectives." In the United States, TAM applies to the technical and financial decisions, plans and actions related to physical infrastructure, while TPM considers a broad range of system performance categories.

A graphic illustrating the integration of asset management and performance management is provided in Figure 2-4. In the figure, the circle on the left represents the interconnection of the various performance areas that transportation agencies are concerned with throughout their planning processes. Flowing into the performance circle is the asset management circle, representing an agency's infrastructure needs to support system performance.

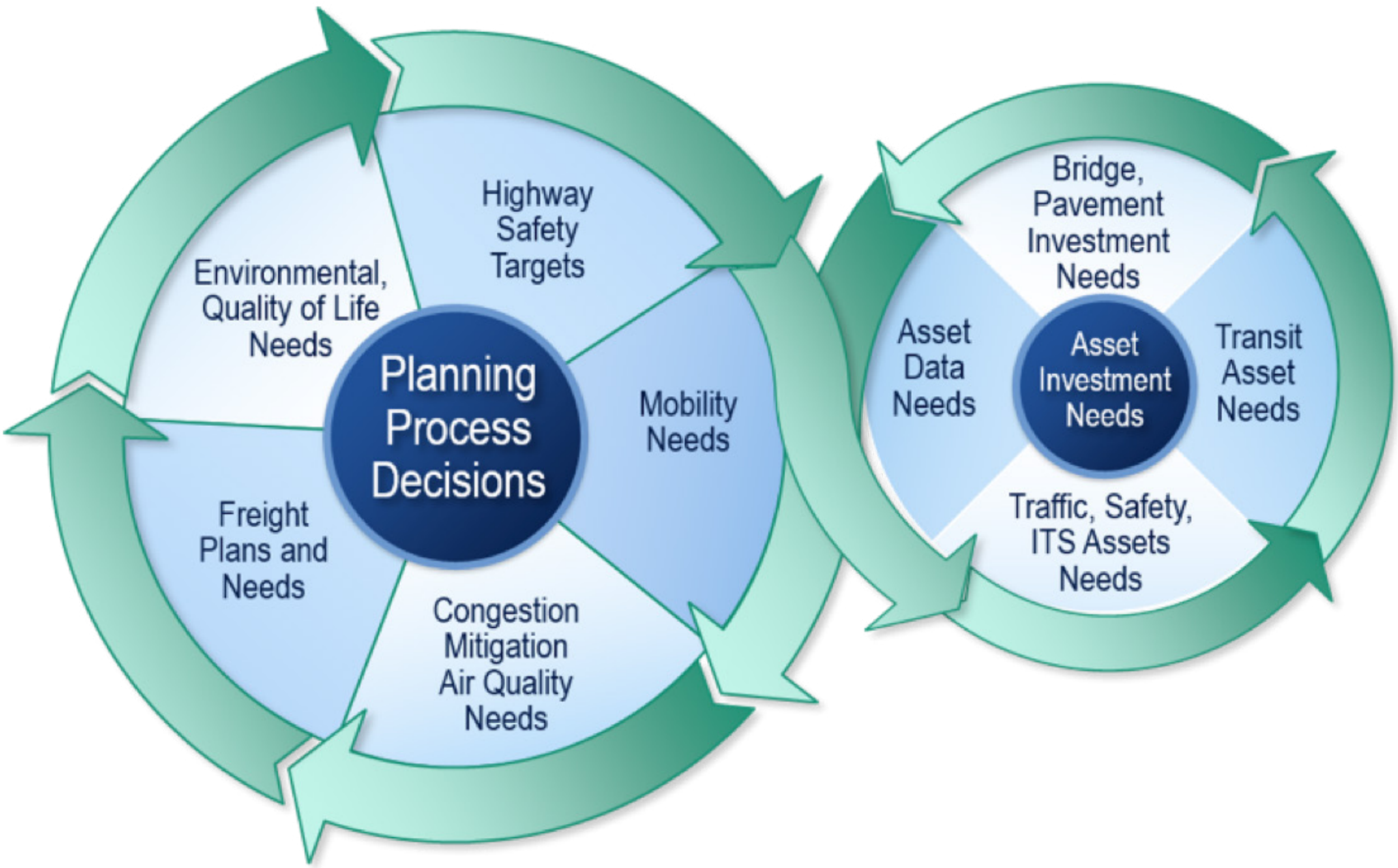
Practice Example
Alignment Between Policies, Investments, and Practices

British Columbia

To support the alignment of agency policies, objectives and day-to-day practices, the Province of British Columbia established the tiered structure shown in Figure 6.3 for a design-build-finance-operate project. The highest of the three levels, Key Performance Measures, defines the high-level outcomes for service delivery in terms of a few key strategic areas. The second level, Asset Preservation Performance Measures, defines the minimum acceptable condition levels for each of the individual assets to preserve their value. The third level, Operational Performance Measures, corresponds to the many specific requirements for operating and maintaining the highway in a safe manner on a day-to-day basis. The tiered approach helped align stakeholders at all levels and clarified priorities for all parties.

The FHWA's Expert Task Group (ETG) published a white paper explaining the relationship between asset management and performance management. It acknowledges the performance of a transportation system is dependent on many factors, including operational characteristics, and system usage and demand, in addition to the physical condition of the infrastructure assets. The paper explains that "performance management focuses on how policies, resource allocation, and other decisions affect all aspects of system performance including safety, operations, environmental stewardship, and infrastructure condition." (FHWA 2012) Asset management is described as an application of performance management principles with a long-term focus to manage the performance of infrastructure assets, the resources allocated to operate a transportation system, and the investments made to achieve the agency's long-term goals and objectives.

Figure 2.4. Integration of Performance Management and TAM



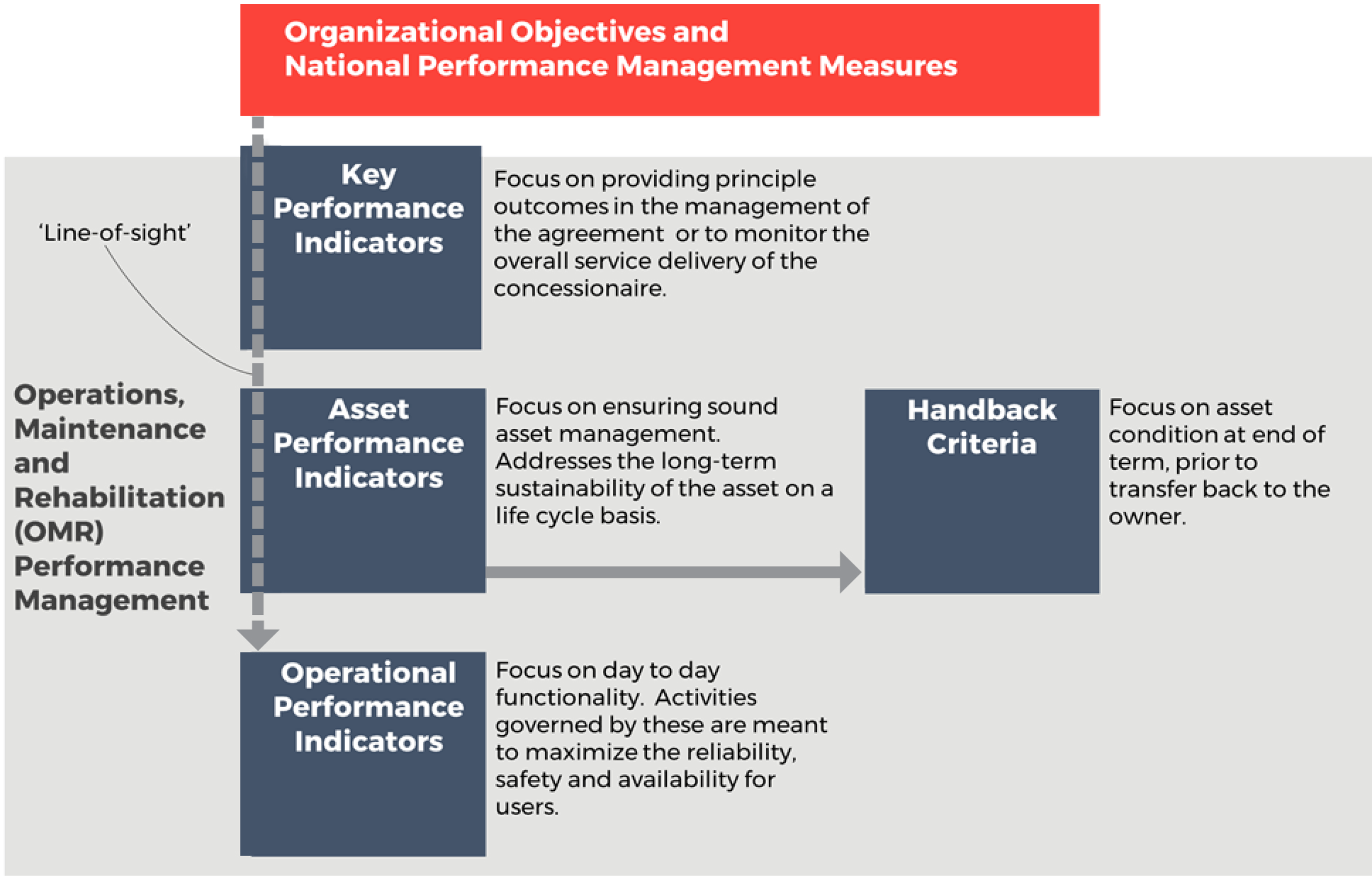
Source: NHI 136106A, *Introduction to Transportation Asset Management*. 2019

Performance Management Framework

To support the alignment of agency policies, objectives and day-to-day practices, agencies may establish a tiered performance management framework, such as the example illustrated below for a model Design-Build-Finance-Maintain-Operate (DBFMO) project (Figure 2.5). The highest of the three levels, Key Performance Measures, defines the high-level outcomes for service delivery in terms of a few key strategic areas. The second level, Asset Preservation Performance Measures, defines the minimum acceptable condition levels for each of the individual assets to preserve their value. The third level, Operational Performance Measures, corresponds to the many specific requirements for operating and maintaining the highway in a safe manner on a day-to-day basis.

Further discussion on Performance Management Frameworks, defining Performance Measures and Performance Targets is included in Chapter 6.

Figure 2.5. Typical Performance Management Framework used in a DBFMO Project



Risk Management

Managing transportation assets entails managing risk. This includes day-to-day concerns, such as addressing the risk that assets will deteriorate faster than expected or projects will cost more than budgeted. However, managing risk also involves enterprise-level risks with widespread impacts.

FHWA defines risk and risk management, in the context of transportation asset management, as follows:

- Risk: The positive or negative effects of uncertainty or variability upon agency objectives. (23 CFR 515.5)
- Risk Management: The processes and framework for managing potential risks, including identifying, analyzing, evaluating, and addressing the risks to assets and system performance. (23 CFR 515.5)

Considering risk is important in developing TAM strategies, because transportation agencies often must spend significant resources responding to and/or mitigating risks. Reacting to the uncertainty presented by risks can be more expensive than proactive management. Risk management strengthens asset management by explicitly recognizing that any objective faces uncertainty, and by identifying strategies to reduce uncertainty and its effects. Being proactive, rather than reactive, in managing risk and avoiding "management by crisis," helps agencies best use available resources to minimize and respond to risk as well as further build public trust.

Given the importance of risk management for supporting asset management, agencies should formally identify and manage risks at all organizational levels. Figure 2.6 shows four levels at which risks can be identified within an agency, and the individuals who may be responsible for the risks at each level.

Typically agencies manage risk every day. They are well-equipped to hand risks at the project and activity levels, and regularly consider risks on a larger scale. Formally considering and documenting potential risks at all levels can help bring greater attention to them and improve risk management.

Figure 2.6 Levels of Risk within an Organization

Enterprise: Risks to the organization's strategic objectives, or which involve multiple levels.
Responsibility: Senior executives, policy makers.

Program: Risks that are common to groups of projects that achieve strategic goals.
Responsibility: Program managers.

Project: Risks that are specific to individual projects.
Responsibility: Senior executives, policy makers.

Activity: Risks that are specific ongoing functions that support programs or projects.
Responsibility: Activity managers.

Source: TRB. 2016. ***NCHRP Project 08-93 Final Report***. http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-93_FullGuide.pdf

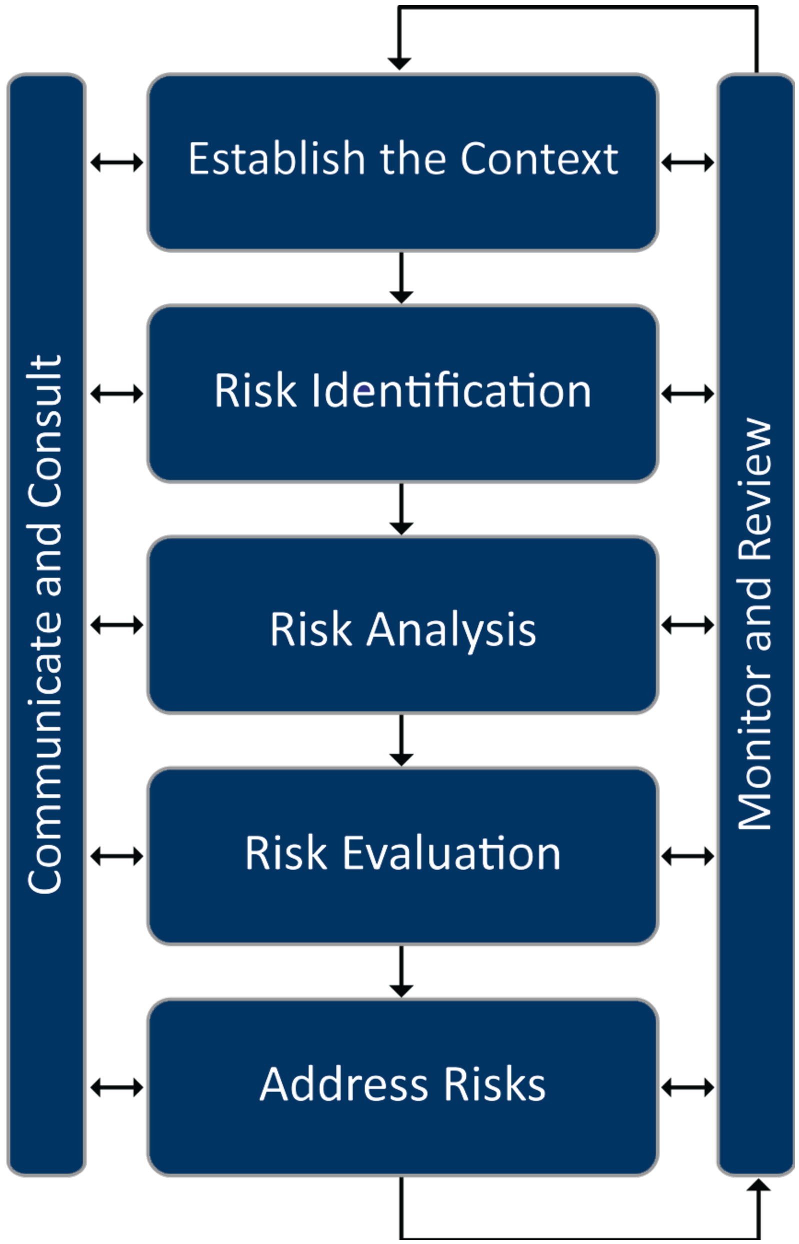
TIP Risk management workshops or discussions should involve as many people in as many different parts of the agency as possible. This ensures that a broader range of risks and categories of risks are included.

Risk Management Process

Figure 2.7 depicts a risk management process. While it may not be necessary to walk through each discrete step in this process for every risk an agency faces, this process is helpful for understanding how to incorporate risk into TAM.

- The process starts with **establishing the context** for risk management. In the case of risk management for a TAMP, the context is largely defined through other TAMP development steps.
- The second step involves **identifying the risks** that affect the assets in the TAMP. Ideally, in this step the agency considers the full set of asset-related risks, even those that may appear insignificant.
- The third step, **risk analysis**, involves identifying the cause of the risk, the outcomes or consequences (impact), and the likelihood of the risk occurring.
- The fourth step, **risk evaluation**, entails prioritizing and ranking risks.
- Fifth, the **address risks** step is the response the agency takes to the risk. DOTs can choose to tolerate the risk or treat the risk in some manner.
- The left side of the figure shows a continuous **communication and consultation** activity. Agencies need to communicate the risks to both internal and external stakeholders, as well as monitor and review the risks.
- The right side of the figure shows an iterative **monitoring and review** process. Once the risks are identified, analyzed, and a mitigation plan is in place agencies need to monitor the risks and update the risk management documentation accordingly.
- More on risk monitoring and management is discussed in Chapter 6 Monitoring and Adjustment.
- This process is generally consistent with ISO Standard 31000, as well as FHWA's requirements for state DOTs to assess risks to NHS assets in developing a TAMP.

Figure 2.7 Risk Management Process



Source: Adapted from FHWA. 2017. *Incorporating Risk Management into Transportation Asset Management Plans: Final Document*. https://www.fhwa.dot.gov/asset/pubs/incorporating_rm.pdf

Risk Register

It is common practice to develop a register identifying major risks and assess each based on expert judgment. In this fashion, the process is valuable for identifying "non-programmatic" risks, or risks not previously addressed in any one program. The How-To Guide in this section describes the steps in developing a risk register to identify such risks. Once a risk has been identified and assessed, formal processes may be required to perform a more detailed assessment and manage the risk programmatically, as illustrated in the Arkansas practice example.

Practice Example
Risk Register Development

Arkansas DOT

As part of the process of developing its 2018 TAMP, ARDOT developed a risk register and mitigation plan compliant with FHWA TAMP requirements. As part of this effort, ARDOT first reviewed and documented its existing controls for asset-related risks incorporated in its design specifications, and approaches for addressing specific risks to bridges (e.g., scour). The agency then developed an initial register through a risk workshop. In the workshop, ARDOT staff identified specific risks not otherwise addressed programmatically, classifying risks by type:

- Asset Performance
- External Threats
- Business Operations
- Highway Safety
- Finances
- Project and Program Management
- Information and Decision Making

For each risk ARDOT used expert judgment to classify the risk in terms of its likelihood and impact. An initial priority was determined based on this classification. Next, ARDOT defined potential mitigation strategies for each of the 14 high-priority asset management risks in the register. A total of 12 strategies were identified, with each helping to mitigate one or more different risks. ARDOT next prioritized the mitigation strategies, and developed mitigation and monitoring plans detailing actions to be undertaken, and the approach for monitoring the risks and updating the register moving forward.

Source: Arkansas DOT. 2018. ArDOT Risk-Based Transportation Asset Management Plan. http://www.tamptemplate.org/wp-content/uploads/tamps/037_arkansasdot.pdf

How-to

Develop a Risk Register

Risks may have important implications for an agency's resource allocation decisions. A risk register is a way to identify, analyze, and monitor risks that transportation agencies face. Developing a risk register helps accomplish a number of the steps in the risk management process and keeps the risk management process organized. This How-To Guide provides nine steps for developing a risk register.

1. Review Existing Resources

Review what programs or initiatives the organization has already established for risk management. This may include agency-wide enterprise risk management efforts, as well as programs to mitigate specific risks such as risks to bridges, or procedures for minimizing risks of project cost and schedule overruns.

2. Determine Register Scope

Next determine the scope of the risk register. What types of risks will be included? What assets are being considered? Are there specific risks that should be excluded because they are already being addressed through a separate program?

3. Identify Risks

Prepare master list of risks. It is often helpful to identify risks in a workshop setting. Classify the risks according the type/scopes identified in Step 2. For each risk prepare a risk statement describing the risk and the consequence to the agency if the risk is realized as an "if-then" statement.

Likelihood \ Impact	Very Low (Insignificant)	Low (Minor)	Medium (Moderate)	High (Major)	Very High (Catastrophic)
Very High (>1x/Year)	Medium	Medium	High	Very High	Ultra High
High (~1x/Year)	Medium	Medium	Medium	High	Very High
Medium (1x/3 Years)	Low	Medium	Medium	High	High
Low (1x/10 Years)	Very Low	Low	Medium	Medium	High
Very Low (<1x/10 Years)	Very Low	Very Low	Low	Medium	Medium

How-to

Develop a Risk Register

4. Analyze Risks

For each risk that is identified, calculate or estimate the likelihood the risk will occur, and the consequence or impact of the risk if it does occur. Often this step is performed qualitatively using a risk matrix. An example matrix is shown on the previous page. In this example risk likelihood is depicted on the vertical axis, and impact or consequence is shown on the horizontal axis.

5. Perform Initial Prioritization

Determine an initial priority for each risk to help determine where to focus further effort identifying treatment strategies. In the matrix above, an initial priority is defined for each combination of likelihood and consequence.

6. Evaluate Potential Risk Management Strategies

For high priority risks (or all risks if time allows), determine potential strategies for mitigating the negative effects of a risk, and/or leveraging the positive effects. Strategies might include treating the risk in some manner, transferring the risk to another party, avoiding the risk altogether, or accepting the risk with treatment. Evaluate the potential for reducing the negative impacts of each risk.

7. Prioritize Risk Management Strategies

Prioritize the risk management strategies developed in the previous step. The prioritization should consider the severity of the risk, the potential for treating the risk, and the cost of the strategy. For example, a treatment may have low priority if it does little to reduce the likelihood or impact of a risk, even if the risk itself has high priority. In some cases the strategy may entail collecting additional data, and/or performing a more detailed analysis to better characterize a risk and determine the investments needed to best address it.

8. Develop Mitigation Plan

Given the prioritized set of risk management strategies, prepare a mitigation plan that describes the actions needed to implement the highest priority strategies. This may include a mix of process improvements, data collection efforts, and/or projects to treat or avoid risks.

9. Establish Monitoring Approach

Determine how the organization will monitor the risks moving forward. The plan should describe the approach for implementing the mitigation plan, as well as for reviewing and updating the risk register.

Developing a Risk Register

1. Review existing resources
2. Determine register scope
3. Identify risks
4. Analyze risks
5. Perform initial prioritization
6. Evaluate potential strategies
7. Prioritize risk management strategies
8. Develop mitigation plan
9. Establish monitoring approach

Information Management

Planning and Programming, Performance Management and Risk management are activities that form components of the asset management framework within an agency. They are necessary to manage the infrastructure portfolio, and the services it supports.

Asset management relies on good data and tools to guide investment decision-making. Indeed many agencies have a wealth of data about their infrastructure, but are challenged to leverage information to make better decisions. Information management is the discipline that delivers foundational capabilities for asset management results. Asset management systems connect inventory and condition with analytical capabilities to predict asset condition under various funding and action scenarios. Other information and tools allow for the ability to relate asset actions across assets and with other transportation areas, such as safety and mobility. This section provides a brief overview of information management and how it supports the implementation of the concepts discussed in this guide. More detail can be found in subsequent Chapters. Each section has been crafted to illustrate how data, information and analysis can be leveraged to create better outcomes, and enable agencies to improve how they deliver services.

Data Collection Standards and Processes

Standards and processes for data collection are two important aspects of integrating asset management practices across the agency. Collecting a standard set of data elements for each asset ensures consistency, and better enables analysis and reporting across assets. Standard data elements can include a unique asset identifier, designated asset category and asset type. Geospatial referencing standards are also important. In order to see assets on a map and integrate them spatially, agencies need a standard way to locate them. It is also important to consider the data collection intake process. Before data is collected, agencies should determine if specific data already exists in order to prevent duplication. If the data does not exist and needs to be collected, agencies should consider how new data will integrate with what is available currently. This ensures the data is used in the most effective way possible. Finally, responsibility needs to be assigned to an Asset Data Steward who is responsible for ensuring data standards and processes are followed.

Asset Information Across the Life Cycle

TAM integration also relies on collecting and updating asset information across the life cycle of the asset. It is important to think holistically about the asset life cycle, from the initial design phase and through future maintenance and rehabilitation activities. Technologies and processes are becoming available to extract asset information from design and as-built plans to populate inventories. Many agencies have processes in place to think holistically about assets during the project scoping and design phase.

TIP **Data for asset management purposes can often be pulled from existing datasets that are used for other purposes. Alternatively, data collected for TAM purposes can often be used to fulfill other agency responsibilities.**

Agencies face challenges in integrating asset information across the life cycle of the asset, because there is often a disconnect between maintenance activities, planning/ programming and the assets. For example, maintenance divisions may not know about planned projects on particular assets that have been scheduled for repairs. Better linkage between the work an agency is planning for the future, the work they are doing currently and the general condition of the assets is important to cultivate. Maturing agencies are working hard to bridge this gap. Chapter 6 provides more information on updating asset information and connecting with maintenance activities.

Common Set of Asset Management Reporting Processes

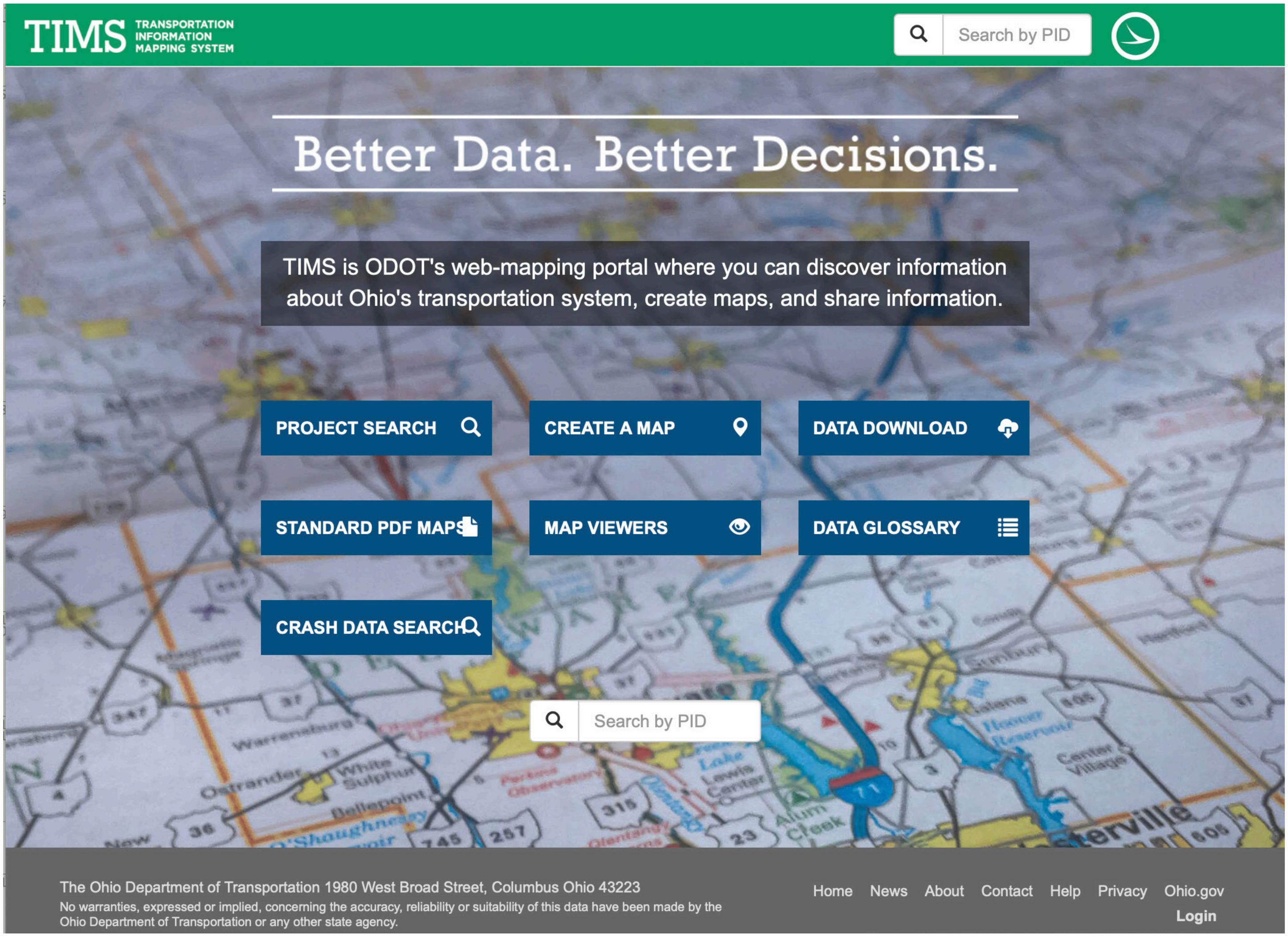
Another aspect of information management strategy that can help integrate TAM across an agency is to develop a common set of asset management reporting processes. Many agencies are successfully mapping different types of assets and making this information available on a GIS portal. Typically, these portals have different layers for each asset. This is one example of a consistent process for sharing information about assets.

As agencies seek to make cross-asset tradeoffs and scope projects considering multiple types of needs, having a common set of reporting processes and consistency across different tools becomes even more important. An example of the challenge agencies face in doing this is seen in the TAMP development process. Developing a TAMP requires information about the needs of different assets. This information must then be communicated with a common set of definitions and combined with funding information. Practitioners have to be aware of the funding and cost assumptions used in every tool before they can report numbers in the TAMP. For instance, the pavement management system might only include costs for the pavement work, whereas other planning tools might incorporate guardrail costs and other costs related to the work. Different tools might also use different assumptions for inflation. In order to bring all this information together in a TAMP, agencies need to make sure their reporting and assumptions are consistent.

Practice Example
Transportation Information Mapping System (TIMS)

Ohio DOT

Ohio DOT (ODOT) has focused on data and information management improvements as a foundational element of their asset management program. As part of this they have strengthened their geographic information system (GIS) and linked it to over 100 data sets. The agency's TIMS allows users to make collaborative decisions based on shared access to the same data sets.



Source: Ohio DOT. *TIMS*. https://gis.dot.state.oh.us/tims/

Section 2.3

TAM Assessment and Advancement

Developing and implementing asset management can follow an incremental approach that helps shape processes over time. Asset management processes should be appropriate to the organization, the type of decision being made and the accuracy required in the decision-making process. Agencies may not always be ready for full-scale implementation of TAM, and incremental implementation can help make the best use of limited resources for managing assets while supporting management of the change introduced with improved asset management practice. A primary step in incremental asset management implementation is understanding the current strengths, weaknesses, achievable improvements and the areas where the most benefit can be gained.

This section has four parts:

1. **Assessing Current Practice.** When assessing current practice, it is beneficial to use a framework providing an industry recognized reference that defines aspects of practice requiring evaluation.
2. **Defining and Prioritizing Improvement in TAM Approaches.** When defining improvement areas it is necessary to prioritize the extent to which assets will be managed.
3. **Developing a TAM Implementation Plan.** Once improvement actions are agreed upon, an implementation plan must define, communicate and empower change.
4. **Monitoring TAM Program Improvements.** Monitoring progress enables reporting of success, identifying areas of further focus and enabling adjustments.

Assessing Current Practice

An assessment of current agency competency against industry-leading practice enables an agency to assess a desired future performance level. It can also help to identify the steps required to reach that goal.

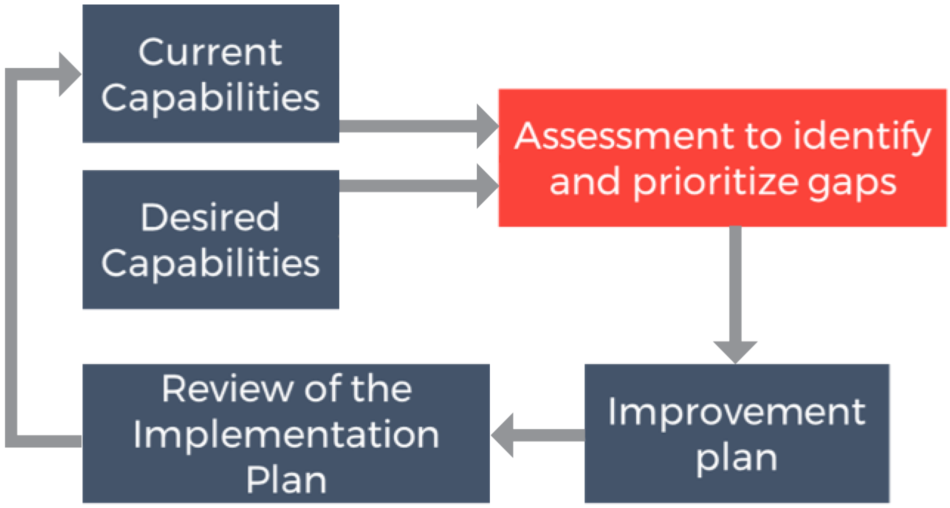
TAM is an evolving process; ongoing improvement is an important component for a TAM program. In fact, the ISO 55001 Asset Management certification requires ongoing assessment and continual improvement.

A gap assessment process is used to understand how well an agency aligns with an established asset management framework. The gap assessment can be conducted internally or by a third party. Organizations seeking or wanting to maintain ISO certification will also undergo a formal third party audit.

The results of a gap assessment can help agencies identify changes in business processes needed to better link plans and decisions and better align to leading practice.

NCHRP Project 08-90 led to the development of a gap analysis tool, available through AASHTO and the TAM Portal. Figure 2.8 illustrates how this assessment tool is intended to be used. There are several other frameworks that can be used, including ISO 55001 and the Institute of Asset Management (IAM). A range of gap assessment framework's are discussed further in Figure 2.9. Each framework, process or tool will enable an agency to assess current performance and, from this, identify a desired capability level.

Figure 2.8 TAM improvement cycle
Modified from original in NCHRP Project 08 90



TIP Factors to consider when prioritizing advancement in TAM approaches will vary from agency to agency. Consider those factors that are of most importance to you and are well aligned to your strategic goals.

Table 2.1 Frameworks for Assessing Current Practice

Framework	NCHRP 08-90 Gap Analysis Tool	ISO 55001 Asset Management Gap Analysis	International Infrastructure Manual (IIMM)	IAM Self-Assessment Methodology
Background	This tool was developed based on the previous tool and process created through development of the 2011 AASHTO TAM Guide. Uses a point scale for evaluating current and desired capabilities. https://www.tam-portal.com/resource/aashto-transportation-asset-management-gap-analysis-tool-users-guide/	This is the most widely adopted standard for asset management globally. It is generic to accommodate many contexts. Describes a management system approach to asset management. https://www.iso.org/standard/55089.html	Recognizing that the ISO Standards for asset management are very much the "What to do," the IIMM provides the "How to do it." Identifies an Asset Maturity Index (Aware, Basis, Core, Intermediate, Advanced) to identify the current and an appropriate level of asset management for each asset. **https://www.ipwea.org/publications/ipweabookshop/iimm**	As an aid to the application of ISO 55001, the IAM decided to update their methodology into one that enables organizations in all sectors to measure their capabilities against the requirements of both PAS 55 and ISO 55001. https://theiam.org/knowledge/Knowledge-Base/sam/
Assessment or Focus Areas	• Policy goals and objectives • Asset management practices • Planning, programing, and project delivery • Data management • Information systems • Transparency and outreach • Performance Results • Workforce capacity and development	• Leadership • Planning • Support • Operation • Performance Evaluation • Improvement	• Understanding and Defining Requirements • Life cycle Planning • Asset Management Enablers	• Organizational Strategic Plan • Organization and People • Strategy and Planning • Asset Management Decision Making • Life cycle Delivery • Risk and Review • Asset Information
Why use this framework?	This framework is best for an agency that wants to work explicitly within a US-defined context that adopts wider influences. Since this tool can be fully customized by an agency, an agency that wants to tailor the analysis to their particular needs will find this useful. Finally, the tool facilitates the analysis of data, and can generate graphs and charts using the data imported into it.	This framework is ideal for agencies that want to adopt a world-recognized approach to asset management that provides a developed asset management lexicon. This is currently the most internationally-recognized standard in the world.	This framework has been refined over time with many examples that illustrate successful application of concepts by organizations. Public agency focused, and largely written for the asset management practitioner responsible for civil assets.	This standard is well recognized internationally, is applicable to all infrastructure asset classes, and has applicability to infrastructure owners in both the private and public sector. It has many other resources developed along with the framework including training materials, reference guides and courses to improve agency skills.

In some cases, agencies also seek benchmarks that reflect how peers are performing to help them decide on the level of maturity and complexity to which they should aspire. ISO 55001 trends away from this. It encourages agencies to check against a framework of practices and process, and select what is best for the agency. Chapter 6 addresses benchmarking and related topics.

Actions to close gaps between desired and actual performance should be addressed within a TAM improvement or implementation plan.

Undertaking a gap assessment can form an important part of a change management process by aligning those within the agency on current performance, opportunities and targets for improvement.

Practice Example • Assessing Current Practice

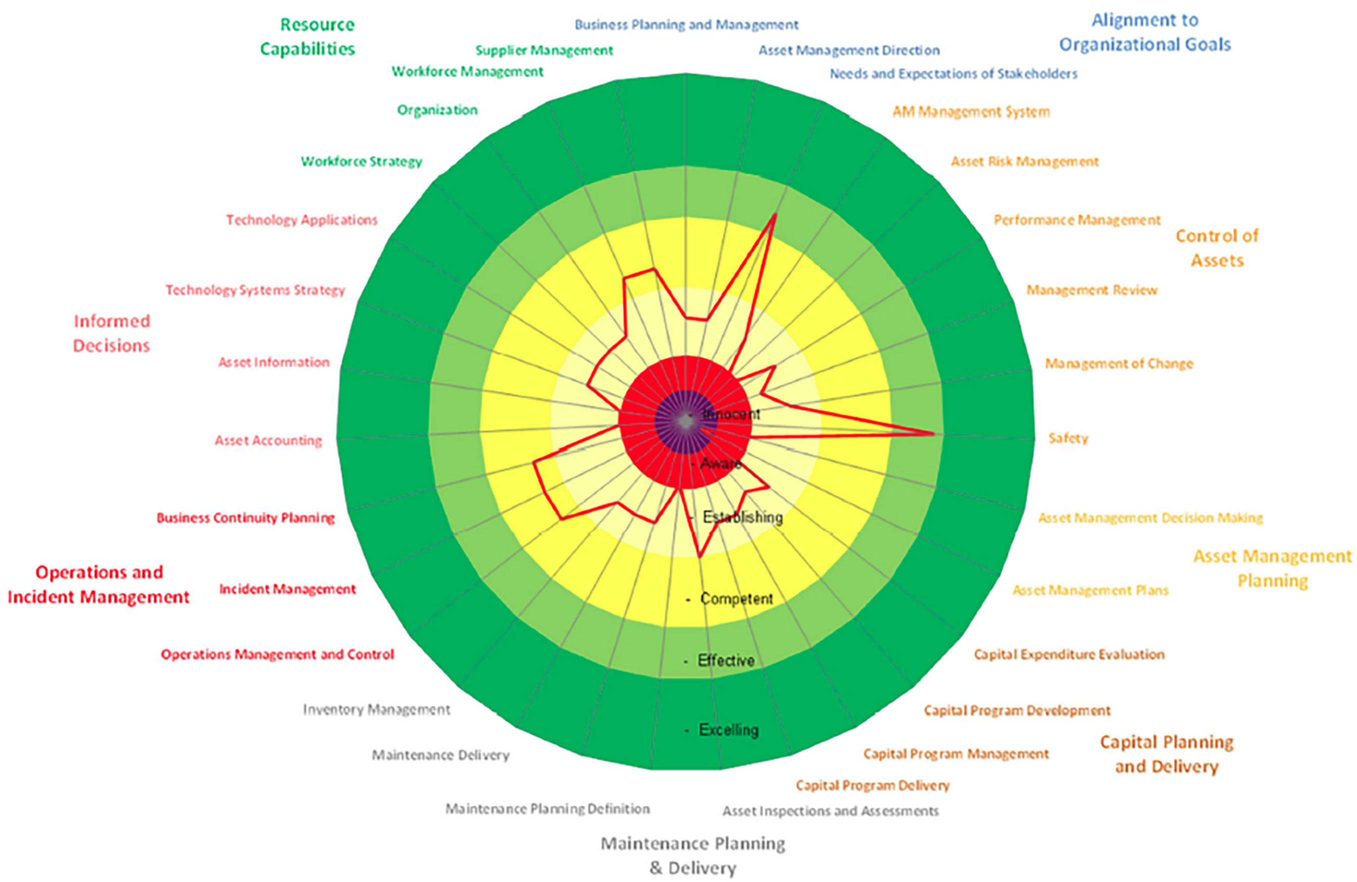
Amtrak Engineering Asset Management Capability Assessment

In 2016, Amtrak Engineering undertook an Asset Management Capability Assessment which bases maturity on the degree of formality and optimization of processes. The assessment uses several questions grouped into eight assessment areas, which describe operational processes necessary for asset management success. This maturity methodology is aligned with emerging guidance from the Institute of Asset Management (IAM), ISO 55001 standards, and requirements of the US FAST Act.

The assessment used a six-point scale, scoring Amtrak at the Establishing level, indicative of an agency that is actively developing asset management capabilities and establishing them to be consistent, repeatable, and well-defined.

Based on the 2016 assessment results, key challenges were identified and a series of improvement recommendations were developed and integrated into an Asset Management Improvement Roadmap.

In addition, Amtrak established a target position, driving process implementation priorities, with the intention of continuous monitoring by repeating the capabilities assessment process on an annual basis.



2016 Amtrak Asset Management Capabilities Assessment Results
Source: Amtrak Engineering 2019

Defining and Prioritizing Improvement in TAM Approaches

Agencies managing different types of assets are faced with the decision of where to prioritize advancing formal asset management. Determining where to improve the organizations effort can depend on different factors, but should always align with the organizational context and priorities.

For transportation agencies, asset management typically begins with the high-visibility, high-value assets, such as pavements and bridges. However, operating the transportation system requires a supporting cast of assets, typically referred to as ancillary assets, that include lighting structures, roadway signs, ITS assets or even operations facilities and technology hardware components. Establishing the appropriate management approach, and future desired approach for each asset is an essential step in strategic planning for asset management, defining boundaries around the effort. Furthermore, for each type of asset, it is important to determine how broadly to define the inventory of assets, such as the decision to include only arterial roads initially or all roads in a network.

Defining Appropriate Management Approaches for Different Asset Categories

An appropriate approach to manage and monitor each asset governed by the TAM framework needs to be established. Depending on the nature of the asset and the level of risk involved, different approaches can be selected by an agency.

Structuring asset management also involves evaluating different management approaches and defining the appropriate level of maturity. There are several approaches to managing highway assets, each with different data needs, and several ways to structure and implement asset management processes. These include:

- **Reactive-Based.** Treatment is performed to fix a problem after it has occurred.
- **Interval-Based.** The asset is treated based on a time or usage basis whether it needs it or not.
- **Condition-Based (Life Cycle Approach).** Select intervention based on a forecasted condition exceedance interval.

Chapter 4 provides more details on these different approaches to managing assets.

Processes and approaches can range in their level of detail and complexity. This is what forms the foundation of some asset management maturity levels. Much like deciding on the scope of assets to manage, the level of advancement of the asset management processes an agency adopts should depend on the context and readiness of the agency, as well as the problem being addressed. Consideration should be given to the data, processes and tools available to support the asset management approaches and processes, as well as resource availability and capability. It is common for an agency to begin at a simple level and mature over time towards more complex asset management that integrates processes and decision-making.

Practice Example
Asset Class Tiers

Utah DOT

To accomplish the objective of allocating transportation funding toward the most valuable assets and those with the highest risk to system operation, UDOT developed a tiered system of asset management. Asset Management tiers range from one to three with tier one being the most extensive management plan for those assets having the highest combination of system level risk and asset value.

Tier 1. Performance-based management

- Accurate and sophisticated data collection
- Targets and measures set and tracked
- Predictive modeling and risk analysis
- Dedicated funding

Tier 2. Condition-based management

- Accurate data collection
- Condition targets
- Risk assessment primarily based on asset failure

Tier 3. Reactive management

- Risk assessment primarily based on asset failure
- General condition analysis
- Repair or replace when damaged

Source: Utah DOT. 2018. ***Utah TAMP***. https://www.tamptemplate.org/tamp/053_utahdot/

Prioritizing TAM Improvements

Deciding on the appropriate management approach and level of asset management is a strategic decision that should consider several factors:

Organizational Strategic Goals

The decision of which assets to prioritize should be driven by the organization's strategic goals. A desire to focus on one aspect of the transportation system over another in order to meet a larger objective can present a good reason for prioritizing some assets over others.

Asset Value

A common consideration for selecting assets to include is the financial value. Monetizing value provides a consistent way of comparing asset classes. In general, assets that are the most expensive to replace or cause the greatest financial concern for an organization fall into the highest priority. Strategic management of these assets means strategic investments over the life cycle of the asset, which will prevent or delay the need for significant additional investment, help avoid premature failure, and allow time to plan for appropriate replacement.

Data Availability

TAM as a concept is heavily dependent on data. Deciding on which assets to focus on based on existing data collection and management practices and will often support achievement of "quick wins." Data availability does not always indicate strategic priority or risk exposure of the asset, but can still be an important factor in selecting assets to include the cost of collecting and analyzing data to form the basis for more advanced TAM decision making can in some instances be significant, and require new skills and training.

It should be recognized that data does not need to be comprehensive and complete as a basis for TAM decision making. An accepted approach is to group assets into classes (age, type, function) and then inspect a sample set. This can provide important insights to guide long-term planning at minimal initial expense/time. It can also highlight any issues with particular types of assets and allow for more detailed inspections to be undertaken if required. A gap analysis to define future data requirements and determine how to collect this data should be considered for long term TAM outcomes.

Risk of Failure

Often, it can be necessary to consider including assets if the probability and consequence of failure is significant. Assets with a high risk of failure can be a high priority due to the potential losses to the agency and its stakeholders should they fail. Asset management can alleviate or prevent the impact of failure.

Asset Criticality and Network Reliability

Decisions to formally manage certain assets can be based on their importance to the service provided, such as operations, or the importance of the travel paths under consideration. Defining criticality is context specific, but is important, since user experience is based on the journey, not the specific assets. Considering criticality in selecting assets to include in TAM will ensure that the most important assets–those necessary to maintain network reliability–are managed first.

Stakeholder Influence

In general, the scope of TAM should be agreed to in coordination with leadership and influenced by stakeholders. Stakeholders can be any asset owners, metropolitan planning organizations (MPOs), cities, tolling authorities, P3 concessions, federal (mandated requirements), and others. The public can also be stakeholders who influence which assets to include, especially when high-profile incidents potentially attributed to the state of good repair occur.

Practice Example
Selecting Assets to Include

Aurizon Network Asset Management Scoping

Aurizon is Australia's largest freight rail operator, transporting more than 500 million tons of coal to markets including Japan, China, South Korea, India, and Taiwan, in addition to over 800 million tons of freight through an extensive network throughout the country. Aurizon Network manages the largest heavy-haul rail infrastructure network in the country. The network is economically regulated by the State through a process that sets investment levels and tariffs. Asset management practice is well-entrenched in the organization, with a focus on "optimizing the life of assets, keeping a tension between investment in maintenance and capital." The scope of the Aurizon Network asset base, known as the Regulated Asset Base, includes all assets used in the provision of the rail infrastructure service. Management is informed by external engineering standards and legislative and regulatory obligations including:

- Prevention and intervention levels specified in an Asset Maintenance and Renewals Policy.
- Commitments to the Central Queensland Coal Network.
- A Safety Management System aimed to minimize safety risks.
- Network Strategic Asset Plan models which are based on asset age, predicted condition and historical and forecasted usage.

Source: Aurizon. 2019. ***Network: Planning and Development.*** https://www.aurizon.com.au/what-we-deliver/network#planning---development

How-to

Prioritize Assets for TAM Advancement

There are several ways to prioritize assets for advancement in TAM. Agencies can adopt analytical prioritization approaches, such as multi-criteria decision-making, or a more informal approach based on best judgment. In either case, the following How-To can guide the selection of assets to prioritize. Priorities should be periodically evaluated to phase in new assets and capabilities over time.

1. Understand the existing approach for each asset

A gap assessment process enables definition of an existing position with regard to assets, ownership, condition, management approach and risks and the most appropriate next steps in advancing TAM practice.

2. Determine the assets to prioritize

Consider the following questions when deciding which assets should be advanced:

- Which assets merit the greatest level of management attention? What are the current priority areas?
- Which assets, if they fail, would present the greatest risk to the service provided by the network? Which assets represent a significant percentage of the total replacement cost of the portfolio? Which assets consume most the O&M budget or have the greatest impact on network availability/reliability?
- Which assets would involve the least effort to advance? Where is the most readily available data?

3. Determine how much of each asset to consider

Road users travel on routes/corridors rather than specific assets. Consider how the asset-class priorities translate to network priorities. To do this, consider the following:

- Are the most critical end-to-end routes/strategic corridors covered? Are the most critical paths through the network and the assets on these routes covered?
- Are the appropriate road classifications (Interstate highways/National Highway System/state/primary) covered?

4. Communicate priorities

A TAM improvement or implementation plan defines an agency's next priorities for advancement and the actions to be taken. This should be widely understood by all relevant stakeholders in the organization to help foster buy-in and leverage the contributions of those able to help advance the plan.

Developing a TAM Implementation Plan

A TAM implementation plan can clearly communicate an agency's next steps for TAM and define responsibilities for implementation.

The product of a gap assessment will often take the form of an implementation plan for TAM improvements. These improvements can involve changing behaviors across many business units within an organization. The actions should, therefore, be prioritized and staged to advance one step at a time. When defining actions, it is important to understand the purpose and outcome to be achieved, who is responsible, how long it will take and how many resources are required for it to happen.

Note that a TAM Implementation Plan is different from a Transportation Asset Management Plan (TAMP) described further in Section 2.4. An implementation plan focuses on business process improvement, while a TAMP focuses on an organization's assets and how it is investing in and managing them. However, the implementation plan may be included as a section of a larger TAMP.

The improvements identified need to recognize potential barriers to implementation. As an example, improving decision-making tools will likely require improvements in data practices. The implementation plan should consider any foreseeable obstacles, including staff resistance to new business procedures, lack of support from agency leadership, inadequate skills among staff, data integration issues or outdated analytical tools.

Communicating the Implementation Plan

Effective, organization-wide communication can serve as a powerful tool to facilitate smooth and swift adoption of the TAM implementation plan. At the start of implementation, communicating the future vision and benefits can help build awareness and buy-in. Throughout the duration of the implementation initiative, communication about milestones and accomplishments can help sustain or regain momentum. Additionally, as different projects are initiated, delivered and completed, agencies will want to ensure that the resulting changes in processes, systems and tools are adopted and used consistently to achieve the intended outcomes and objectives. As illustrated in Figure 2.10, the TAM communication strategy should cover six key elements – why, who, what, when, how and how well.

Objectives. Why communicate?

Establishing early buy-in to the implementation plan by providing an upfront explanation of why execution of the TAM implementation plan is needed—the anticipated benefits for the organization as well as for different stakeholder groups—will help jumpstart success of the implementation.

Stakeholders. Who delivers and receives the communication?

To make sure the right people are receiving the right information, it is key to develop and categorize a complete list of internal and external stakeholders who will be impacted by the TAM implementation plan and its resulting changes. In determining stakeholders, consider who needs to receive different types of information and who best to deliver that information to support achievement of implementation plan objectives.

Messages. What are the messages to communicate?

In developing the key messages to communicate, consider intent – what should stakeholders know, think or do as a result of the message? Key messages should promote awareness, desire and reinforcement of the implementation plan and its associated changes. They should also align with objectives of the implementation plan as well as organizational objectives.

Timing & Frequency. When will the communication occur?

Communication about the TAM implementation plan and corresponding changes should be timely, frequent enough to keep stakeholder groups well informed about approaching milestones and key dates of impact, and not so frequent that they lose value. Take into account what is being communicated and to whom, as different stakeholder groups receiving different types of messages often require different delivery frequency.

Practice Example
Implementation Plan

Clackamas County Department of Transportation and Development

Based on their gap assessment, Clackamas County Department of Transportation and Development established a Transportation Asset Management Strategic Plan (TAMSP), which documents its methods to implementing a comprehensive transportation asset management program over a 5 year period. This TAMSP was accompanied by an asset management implementation strategy that identified the key actions to be undertaken.

2.2. Develop the Ability to do Benefit Cost Analysis

Description			Draft, develop, document, and distribute process to complete BCR analysis		
Strategy Owner			Karen Buehrig, Randy Harmon, Rick Nys		
Key Stakeholders			Maintenance, Capital, Safety, TS, AMST		
Deliver Mechanism			Delivered internally with support from external providers		
Timeframe	Start		Financial Year 2022/23 Q4		
	Finish		Financial Year 2023/24 Q2		
	Duration		1 year		
Sequencing	Prerequisite(s)		Life cycle strategies / linking TAM outcomes to strategic goals, data warehouse and enhanced GIS analytical tool, any other relevant policies and procedures, TAM systems (for full implementation)		
	Dependent(s)		TAM systems can be developed without this, but it should be considered in their development.		
Considerations			This process relies heavily on prior tasks.		
Specific Actions			◆ Define current processes (if any). ◆ Identify activities that are needed to address any gaps. ◆ Define discount factors, how benefits will be evaluated and costs to be included (internal and external). ◆ Identify existing processes and determine which process is most applicable. ◆ Define TAM system requirements that support BCR analysis (if applicable — such as InfoHansen). ◆ Document process and circulate for review. Finalize and implement.		
Level of Effort	Hours	Internal Support	300.00	to	600.00
	Cost	Support		to	
		Software, purchases, and configuration	$ 60,000.00		$ 120,000.00
Enabler(s)			◆ Financial / Accounting to understand and evaluate cost factors. ◆ Project specialists to understand benefits from each intervention. ◆ TS support with system development.		
Outputs			◆ Ability to complete BCR analysis supported with process and systems.		
Notes on Estimate					

Source: Clackamas County DOT. *Transportation Asset Management Strategic Plan.*

Tactics & Channels. How will information be communicated?

Depending on the duration of the TAM implementation plan and the number of associated changes, communication needs often shift over the course of its execution. Agencies should determine the most effective types of communication and delivery channels as they progress through change. By including stakeholder categories, messages and frequency as inputs when determining the most effective channels, the communications strategy remains agile, which facilitates continuous improvement.

Continuous Improvement. How well is the communications strategy working?

Assessing the effectiveness or performance of any strategy is important for achieving objectives. Including a stakeholder feedback loop into the communications strategy is one way to accomplish this. Agencies can use surveys, polls, focus groups or meetings to gather information and gauge opposition and support. This crucial feedback serves as guidance for subsequent content and can lead to changes in the communications strategy.

Figure 2.10 Communicating the Plan

Key questions to answer in communicating your implementation plan

OBJECTIVES	WHY communicate?
STAKEHOLDERS	WHO delivers and receives the communication?
MESSAGING	WHAT are the messages to communicate?
TIMING & FREQUENCY	WHEN will the communication occur?
TACTICS & CHANNELS	HOW will information be communicated?
CONTINUOUS IMPROVEMENT	HOW WELL is the communication working?

Ingredients in an Implementation Plan

Agencies can use this checklist when developing and communicating a TAM Implementation Plan. Completing the items on this checklist ensures that the key ingredients are included in the Implementation Plan and lays the foundation for successful improvement.

- ☐ **Have owners been assigned to the individual improvement items?**
- ☐ **Have the benefits of change been identified?**
- ☐ **Have tasks in the implementation plan been prioritized based on potential benefit to the asset management processes?**
- ☐ **Do the prioritized improvement items consider whether the supporting processes have been developed?**
- ☐ **Have the relevant stakeholders been identified?**
- ☐ **Have timelines for change been specified and agreed to between those undertaking and implementing the task?**
- ☐ **Have risks such as interdependencies with other tasks been identified and a mitigation strategy agreed upon?**
- ☐ **Is the level of effort quantified and agreed upon?**

Monitoring TAM Program Improvements

Measuring TAM improvement is important for understanding if the plan needs adjustment, and to communicate success and motivate those responsible for implementation.

Once a commitment to make improvements has been made, the improvement process needs to be managed and monitored.

Regular updates, meetings, performance tracking (monitoring improving performance against the selected framework) and scheduled reviews by the TAM Governance Groups will help provide oversight to those responsible for undertaking the improvements.

This process also helps remove roadblocks by involving leaders from across the organization.

When to Re-Assess Performance

A regular commitment to monitor progress is important. This assessment will compare progress from the initial benchmark toward the desired level of competency. There is no set recommendation for when to assess progress; some agencies find it more important in the early stages of implementation, while others do not.

When considering the timing of progress assessments, it is important to consider:

- **Process checkpoints**. The frequency could be aligned with reporting requirements, but should also consider appropriate points where progress will be noticeable.
- **Commitment.** Undertaking an assessment will take time and resources, so it is important this is balanced against progressing with implementation.
- **Champions and change agents**. As these individuals are critical to the overall success of TAM implementation, if they change or need to monitor their own performance, then a review of progress can help motivate and reset goals.

Measuring Performance Improvements

Monitoring performance of the asset management system and the results of improvement actions can be challenging, as the cost of service delivery, quality of service levels and risk of service failures may shift over time, and can change following the implementation of an improvement action. The IIMM suggests some of the following potential TAM system performance indicators:

- Financial performance
- Data management performance
- Timeliness relative to target response times
- Productivity and utilization of resources
- Skills availability relative to planned requirements
- Adherence to quality procedures

Chapter 6 provides more information on performance measures, targets, and monitoring asset performance. Self assessment can focus both on service / asset outcomes experienced by users, as well as be internally focused to determine how well the agency is aligned with desired practices. It is important that agencies consider and select the appropriate level and focus of self-assessment for their requirements.

TIP **TAM Maturity Assessments should end with an Improvement Program, highlighting areas for self improvement, which can then be prioritized according to agency priorities or strategic direction.**

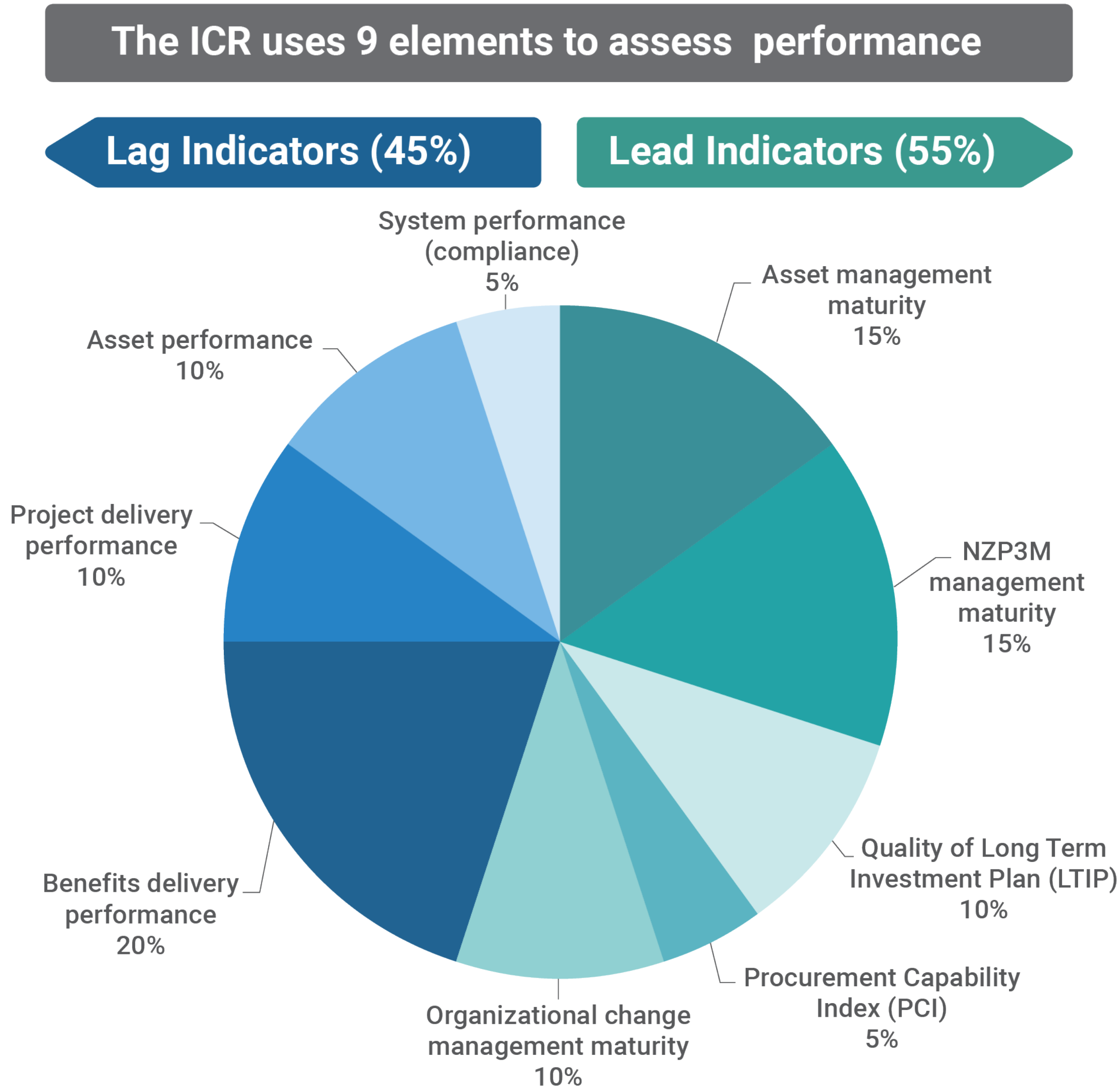
Practice Example
Monitoring TAM Program Improvements

New Zealand Treasury Investment Management Using Asset Management Maturity and Asset Performance

The New Zealand Treasury stewards the NZ government's Investment Management System to optimize value from new and existing investments and assets for current and future generations of New Zealanders. One of the tools the system uses is the Investor Confidence Rating (ICR), which illustrates the confidence that government leadership (i.e. Ministers) can have in an agency's ability to deliver investments that produce the desired results.

The ICR also promotes and provides a pathway for capability uplift. One element of the ICR evaluates the gap between current and target asset management maturity levels on the basis that good asset management practice provides the foundation for good investment management. The Treasury recommends periodic self-assessments using a methodology based on international asset management guidelines and the ISO 55001 standard.

The ICR assessment is conducted every 3 years, resulting in more decision-making autonomy for agencies that obtain a good rating and potential flexibility over investment assurance arrangement.



Source: Adapted from New Zealand Treasury. *Investor Confidence Rating (ICR)*. https://treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/review-investment-reviews/investor-confidence-rating-icr

Section 2.4

Developing a Transportation Asset Management Plan (TAMP)

A Transportation Asset Management Plan (TAMP) is a document that describes an agency's assets and how they will be maintained over time. Developing a TAMP is consistent with best practice in TAM. Also, U.S. transportation departments and transit agencies are required to develop TAMPs to comply with Federal requirements. This section summarizes the elements of a TAMP.

This section has two parts:

1. **The Basic TAMP.** A TAMP should, at a minimum, include a number of basic elements.
2. **Beyond the Basic TAMP.** There are a number of ways agencies may choose to expand the scope of their TAMP and address advanced topics.

Note this section is not intended as a guide for preparation of a TAMP that is in compliance with Federal requirements for TAMP preparation. Separate resources are available detailing requirements for TAMPs including NHS assets to comply with FHWA requirements, and for TAMPs including transit assets to comply with FTA requirements. These resources are listed at the end of the section.

The Basic TAMP

A TAMP describes an agency's goals and objectives for maintaining its assets over time. It describes an agency's most critical assets, and their current condition. It also describes the agency's strategy for preserving its assets, predicts future conditions given the agency's planned investments, formulates and delivers an investment plan, and discusses how the agency manages risks to its assets.

TAMP Requirements

This section discusses the requirements for a TAMP that is consistent with TAM leading practice. A TAMP includes:

- TAM Policies, Goals and Objectives
- Asset Inventory and Condition
- Life Cycle Planning Approach
- Predicted Asset Conditions
- Investment Plan
- Risk Management

Note there are additional specific requirements for a TAMP that is prepared to comply with Federal requirements. State DOTs are required to prepare a TAMP with a 10-year horizon that includes, at a minimum, NHS pavements and bridges. Transit agencies that receive Federal funds are required to prepare a TAMP with a four-year horizon that includes their revenue vehicles, facilities, infrastructure, and equipment (including service vehicles). FHWA provides a checklist of elements of TAMPs compliant with Federal requirements: https://www.fhwa.dot.gov/asset/guidance/certification.pdf . A similar FTA document is available at: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/asset-management/55371/compliancechecklistfy2018_0.pdf.

TAM Policies, Goals and Objectives

A TAMP summarizes an agency's policies, goals, and objectives and describes how its approach to TAM helps support these. For instance, the document might discuss how maintaining assets in good repair supports the organization's broader goals for strengthening mobility and supporting economic development. It may also describe how the organization defines the desired state of repair of its assets, or criteria for evaluating whether or not an asset is in good repair. A clear linkage between TAM objectives and the achievement of wider agency goals should be directly illustrated within the TAMP.

Asset Inventory and Condition

In preparing the TAMP, the agency must decide which asset classes to include in the document, and the level of detail in which the assets are described. For a highway plan, critical assets include pavements and bridges. A TAMP that is prepared to comply with Federal requirements must include these assets on the National Highway System at a minimum. Other assets addressed in a highway TAMP may include, but are not limited to: drainage assets such as culverts; traffic and safety assets such as signs,

TIP: The biggest benefit of developing a TAMP can come from the process as opposed to the product itself. Developing a TAMP can give agency staff a greater awareness of what assets they own, what condition they are in, and how their performance can be influenced by factors and decisions in other parts of the agency.

signals, and lighting; maintenance facilities; and Intelligent Transportation System (ITS) devices. For a transit plan, critical assets include revenue vehicles, facilities, infrastructure (for agencies that operate fixed guideway) and additional equipment, such as service vehicles.

A TAMP should provide a listing, typically in summary form, of the assets the agency has identified for inclusion. For each asset class the document should describe the physical extent of the asset, and current asset conditions. Chapter 3 of this document describes approaches for measuring asset condition and performance. Note that FHWA and FTA have developed specific requirements for reporting asset conditions for highway and transit assets, respectively. However, agencies are not limited to these measures, and may include multiple measures of condition in their TAMP to help provide a complete description of asset conditions.

Often it is helpful to place the data on an agency's asset portfolio's current condition into some context. For instance, the TAMP may include photographs of representative asset condition to help illustrate what is meant by a given value for a performance measure. Also, a TAMP may include historic data on asset conditions to help illustrate condition trends.

Life Cycle Planning Approach

A critical component of a TAMP is a discussion of how an agency maintains its assets over their life cycle. Ideally the agency's approach to life cycle planning should help maintain assets at a target level of service over their life cycle in the most efficient manner possible, while supporting agency goals and objectives. This section of the TAMP should describe the treatments the agency typically performs on its assets, and detail the analytical approaches it uses to assess investment needs, prioritize work, and predict future asset conditions. If the agency has implemented specific management systems for one or more of its asset classes, such as pavement, bridge or enterprise asset management systems, this section should describe those systems and how they are used to support decision making. Chapter 4 of this document provides further detail on life cycle planning.

Predicted Asset Condition

This section of the TAMP should describe how an agency's assets are predicted to perform in the future. The horizon of the predictions should be commensurate with the horizon in the investment plan described in the next section. Typically the planning horizon is at least four years, but may be up to 20 years.

This sections should show what conditions are predicted given expected funding, as well as any gaps between predicted performance and the agency's goals for its assets. This section may include results for multiple funding scenarios, particularly if there is uncertainty concerning future funding, or if including results for multiple scenarios helps document the process used to prioritize funding. For instance, the document might show predicted asset conditions over time given the current funding level, predicted future funding, and scenarios with more or less funding than the predicted level.

Investment Plan

The TAMP should detail planned investments given expected funding. Depending upon the agency size and assets included in the plan, the document might include specific investments the agency plans to make or projected funding levels by asset class and type of work. This section may provide additional details on sources of funding, and the agency's specific strategy for investing in its assets considering available resources.

Risk Management

Managing transportation assets also entails managing risk. Considering risk is important in developing a TAMP, for the simple reason that there are various risks that, if they occur, may impact an agency's ability to follow its TAMP. For instance, the occurrence of a natural hazard may require an agency to

TIP Although they can be combined, do not confuse a TAM Implementation Plan with a TAMP. The Implementation Plan should be actionable with defined monitoring/reporting timeframes for those who have been assigned specific tasks.

spend significant resources in response, to address or mitigate damage. Employing risk management strengthens asset management programs by explicitly recognizing that any objective faces uncertainty, and identifying strategies to reduce that uncertainty and its effects. This section of the TAMP should describe the agency's approach to risk management. It should identify major TAM-related risks and describe the agency's approach to addressing these.

Practice Example

Colorado DOT

To ensure alignment with the requirements of MAP-21, Colorado DOT developed a requirements checklist that provides a quick reference/summary of the legislation requirements. The checklist is based on FHWA guidance (Transportation Asset Management Plan Annual Consistency Determination Final Guidance) that was issued in February, 2018. Its content was provided to help DOTs ensure their TAMPs are compliant and consistent with statute and regulatory requirements.

Required Elements	Indicators the TAMP Meets Element Requirements in 23 U.S.C. 119(e) and 23 CFR part 515
TAMP approved by head of State DOT (23 CFR 515.9(k))	Does the TAMP bear the signature of the head of the State DOT?
State DOT has developed its TAMP using certified processes (23 CFR 515.13(b))	Do the process descriptions align with the FHWA-certified processes for the State DOT? [If the process descriptions do not align with the FHWA-certified processes, the State DOT must request recertification of the new processes as amendments unless the changes are minor technical corrections or revisions with no foreseeable material impact on the accuracy and validity of the processes, analyses, or investment strategies. State DOTs must request recertification of TAMP development processes at least 30 days prior to the deadline for the next FHWA TAMP consistency determination as provided in 23 CFR 515.13(c).]
	Do the TAMP analyses appear to have been prepared using the certified processes?
TAMP includes the required content as described in 23 CFR 515.9(a)-(g) (23 CFR 515.13(b))	Does the TAMP include a summary listing of NHS pavement and bridge assets, regardless of ownership?
	Does the TAMP include a discussion of State DOT asset management objectives that meets requirements?
	Does the TAMP include a discussion of State DOT measures and targets for asset condition, including those established pursuant to 23 U.S.C. 150, for NHS pavements and bridges, that meets requirements?
	Does the TAMP include a summary description of the condition of NHS pavements and bridges, regardless of ownership, that meets requirements?
	Does the TAMP identify and discuss performance gaps?
	Does the TAMP include a discussion of the life- cycle planning that meets requirements, including results?
	Does the TAMP include a discussion of the risk management analysis that meets requirements?
	Does the TAMP include the results of the evaluations of NHS pavements and bridges pursuant to 23 CFR part 667?
	Does the TAMP include a discussion of a 10- year Financial Plan to fund improvements to NHS pavements and bridges?
	Does the TAMP identify and discuss investment strategies the State intends to use for their NHS pavements and bridges?
	Does the TAMP include a discussion as to how the investment strategies make or support progress toward achieving and sustaining a desired state of good repair over the life cycle of the assets?
	Does the TAMP include a discussion as to how the investment strategies make or support progress toward improving or preserving the condition of the assets and the performance of the NHS related to physical assets?
	Does the TAMP include a discussion as to how the investment strategies make or support progress toward achieving the State's targets for asset condition and performance of the NHS in accordance with 23 USC 150(d)?
	Does the TAMP include a discussion as to how the investment strategies make or support progress toward achieving the national goals identified in 23 USC 150(b)?
	Does the TAMP include a discussion as to how the TAMP's life-cycle planning, performance gap analysis, and risk analysis support the State DOT's TAMP investment strategies?
Inclusion of Other Assets in the TAMP in 23 CFR 515.9 (l):	If applicable, does the TAMP include a summary listing of other assets,[2] including a description of asset condition?
	If applicable, does the TAMP identify measures and State DOT targets for the condition of other assets?
	If applicable, does the TAMP include a performance gap analysis for other assets?
	If applicable, does the TAMP include a discussion of life cycle planning for other assets?
	If applicable, does the TAMP include a discussion of a risk analysis for other assets that meets requirements in 23 CFR 515.9(l)(5)?
	If applicable, does the TAMP include a financial plan to fund improvements of other assets?
	If applicable, does the TAMP include investment strategies for other assets?

Source: FHWA. *Transportation Asset Management Plan Annual Consistency Determination Final Guidance.* https://www.fhwa.dot.gov/asset/guidance/consistency.pdf

Beyond the Basic TAMP

This section contains suggestions for developing a TAMP that goes beyond the basic elements of a TAMP described in the previous section. An agency can expand the scope of the TAMP to include additional asset types and systems. An agency may further tailor their TAMP to address specific needs.

TAMP Scope

A highway agency focused on complying with Federal requirements will typically focus on including its NHS pavements and bridges in its TAMP. While these assets make up the greatest portion of a typical state highway agency, an agency may wish to include additional assets in its TAMP. Also, the agency may wish to extend the network scope of the TAMP. In updating a TAMP with NHS pavement and bridges, an agency may include other assets, such as drainage assets, traffic and safety features, or the agency may wish to include all of the assets it owns.

For transit TAMPs, the initial focus is on revenue vehicles, facilities and infrastructure, as these are the assets that require the greatest investment. An agency may wish to expand its TAMP to include additional assets that are important to the systems, albeit less costly, such as bus shelters and signage.

TAM Implementation Plan

As described in Section 2.3, it is often helpful to prepare an implementation plan describing a set of planned business process improvements that an agency intends to undertake to strengthen its approach to TAM. There are many examples of TAMPs that focus specifically on an agency's TAM approach and how it plans to improve its approach. Ideally a TAMP should both describe an agency's assets and planned investments, and detail how it intends to improve its TAM approach. Where an agency has developed both a TAMP and TAM implementation plan, the implementation plan can be incorporated as a section of the TAMP.

TAM-Related Business Processes

An agency may wish to include a discussion of one or more of the business processes related to TAM in its TAMP. Alternatively, there may be other agency documents that provide more detail on these issues that can be referenced in the TAMP. These areas include:

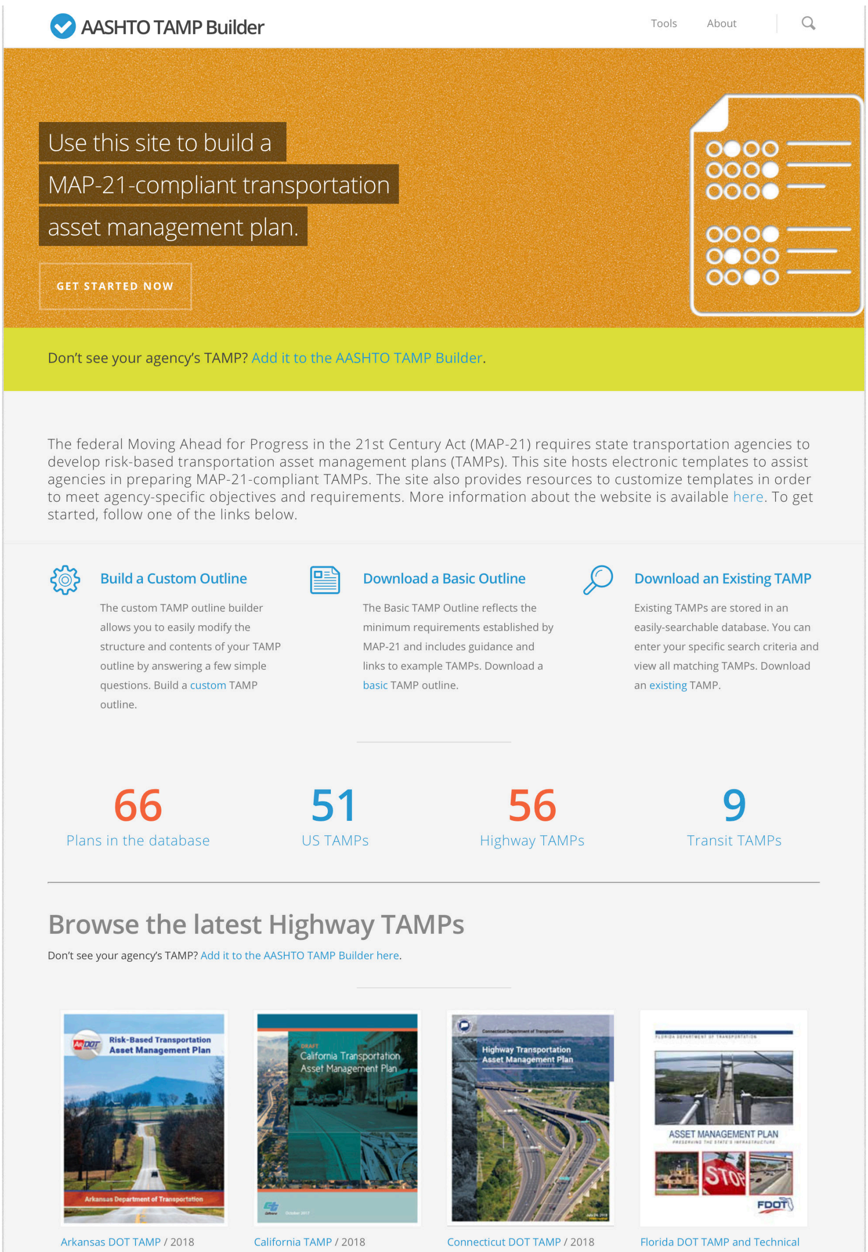
- **Performance Targets.** As described in Chapter 5, setting performance targets can help guide the resource allocation process. However, agencies often have broader efforts to establish and track performance beyond the scope of TAM.

- **Financial Planning.** While developing a TAM investment plan is central to developing a TAMP, often the revenue forecast used to support developing the investment plan is developed separately and used for other purposes beyond the scope of TAM. It may be valuable to document the agency's approach to forecasting future revenues for TAM and other applications. Chapter 5 describes provides additional detail on this topic.
- **Work Planning and Delivery.** As described in Chapters 4 and 5, work delivery approaches can impact how assets are maintained over their life cycle, and how resource allocation decisions are made. Some agencies have adopted formalized approaches for evaluating and selecting different work delivery approaches.
- **Data Management.** Chapter 7 discusses the importance of implementing an approach to data management and governance. Some TAMPs include additional information on this topic given its relationship to TAM.

AASHTO TAMP Builder

AASHTO TAMP Builder

The AASHTO TAMP Builder website (available at https://www.tamptemplate.org/) hosts annotated plan outlines to assist agencies in preparing TAMPs. The site also provides resources to customize an outline in order to meet agency-specific objectives and requirements. The website integrates a database of TAMPs, dating from 2005, that support the functionality of the outlines created using the site.



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
Creating a TAM Policy	**Emerging**	• An Asset Management Policy has been drafted or adopted by elected officials and is guiding in-progress changes to investment and operational decision making in the organization • Policy principles are providing a basis for change and action in the delivery of services with infrastructure.
	Strengthening	• An Asset Management Policy has been adopted and influences capital investment decision making in the organization • The Policy is implemented at high levels within the organization, and its principles help determine overall focus on improving the asset management system action in the delivery of services with infrastructure.
	Advanced	• An Asset Management Policy has been adopted by elected officials and it strongly influences investment and operational decision making in the organization • The Policy is implemented across the organization, and its principles strongly guide process, and action in the delivery of services with infrastructure.
Integrating TAM Within Agency Strategic Plans and Policies	**Emerging**	• Asset management principles are adhered to by some asset management advocates within the agency, but adherence to them is not universal. • Investment is allocated within service areas (Transit, Highways, Active Transportation, Multi-model Systems) and the asset portfolios (pavements, bridges, transit fleet and facilities) that support them, based on the performance management targets that have been set.
	Strengthening	• Asset management principles such as inter-generational equity, triple bottom line decision making, whole of life and service driven decision making can be found in some strategic plans, agency goals and high-level, long term planning documents. • Investment is sometimes evaluated between asset portfolios (pavements, bridges, transit fleet and facilities), and funding is partially allocated based on a linkage to stated objectives.
	Advanced	• Asset management principles such as inter-generational equity, triple bottom line decision-making, whole life and service driven decision making are embedded within strategic plans, agency goals and high-level, long term planning documents. • Investment is systematically allocated between service areas (Transit, Highways, Active Transportation, Multi-model Systems) and the asset portfolios (pavements, bridges, transit fleet and facilities) that support them, based on the requirements to achieve stated objectives and service level commitments.

References

Creating a TAM Policy

Australia State Government Asset Management Accountability Framework. Australia State Government.
Year: 2016
Link: https://www.dtf.vic.gov.au/infrastructure-investment/asset-management-accountability-framework

Balanced Scorecard. Balanced Scorecard Institute.
Year: 2017
Link: https://www.balancedscorecard.org/BSC-Basics/About-the-Balanced-Scorecard

City of Townsville Strategic Asset Management Plan. City of Townsville (Queensland, Australia).
Year: 2015
Link: n/a

How to Develop an Asset Management Policy, Strategy and Governance Framework. Federation of Canadian Municipalities.
Year: 2018
Link: https://data.fcm.ca/documents/programs/LAMP/how-to-develop-asset-management-policy-strategy-en.pdf

Georgia DOT Asset Management Policy. Georgia DOT.
Year: 2018
Link: http://mydocs.dot.ga.gov/info/gdotpubs/Publications/4B-1.pdf

TAM Integration

Building a Better Tomorrow: An Infrastructure Planning, Financing and Procurement Framework. Ontario's Public Sector.
Year: 2004
Link: http://www.ontla.on.ca/library/repository/mon/7000/10319145.pdf

Integrated Planning and Reporting Manual. New South Wales Division of Local Government, Department of Premier and Cabinet.
Year: 2013
Link: http://www.olg.nsw.gov.au/sites/default/files/Intergrated-Planning-and-Reporting-Manual-March-2013.pdf#page=74

Performance-Based Planning and Programming Guidebook. FHWA.
Year: 2013
Link: https://www.fhwa.dot.gov/planning/performance_based_planning/pbpp_guidebook/

Enterprise Risk Management Guide. AASHTO. Guide discusses the range of risks a transportation agency faces and details how to establish an enterprise risk management program.
Year: 2016
Link: https://erm-portal.com

Section 3.1
Establishing TAM Roles, Responsibilities, and Competencies

Section 3.2
Strengthening Coordination and Communication

Section 3.3
Managing Change

Chapter 3
Organization and People

Section 3.1

Establishing TAM Roles, Responsibilities, and Competencies
provides examples of different organizational models, describes the roles and responsibilities required for asset management, provides information on identifying a "home" for asset management within the organization, and discusses relevant competencies.

Section 3.2

Strengthening Coordination and Communication
delves into both the internal and external coordination and communication required for asset management.

Section 3.3

Managing Change
provides helpful tips and strategies for managing the change that comes with implementing asset management, whether it involves changes in organization, process, systems, technology or culture.

Chapter 3
Organization and People

Asset Management is not possible without the people within the organization who commit to its success. An improved understanding of the various organizational models that support TAM can accelerate an agency's ability to add value through its TAM program and sustain value into the future. In addition, a clear understanding of roles and responsibilities and their interaction can strengthen TAM implementation.

This chapter covers the organizational and people elements that support the asset management process.

Key Terms

Alignment
A consistent understanding of policy and practice across staff. Alignment includes both vertical alignment, or uniformity between levels of the organizational hierarchy, and horizontal alignment, or standardization across geographic and functional areas.

Business Model
The structure that characterizes an organization and creates the potential to derive value, driven by clear goals and substantive continuous improvement strategies.

Change Strategy
A comprehensive approach to change at an organizational level, seeking to address institutional and cultural barriers by anticipating the reception to change, and motivating staff members to embrace progress.

Leadership
A role in guiding an organization that emphasizes empowerment and communicates the potential benefits that motivate change.

Management
A role in guiding an organization that focuses on the impact of change in practice, maintaining alignment, and preventing negative outcomes of change.

Transformational Change
An organizational change with broad impact, requiring effective communication and planning in order to achieve the desired goal, which involves a change of not only business strategy and project management but also organizational culture.

Section 3.1

Establishing TAM Roles, Responsibilities, and Competencies

Identifying a “home” for asset management within the organization is an important decision that agencies need to make. Defining the roles and responsibilities required for asset management is another important step in ensuring a TAM program’s success. Regardless of what organizational model is used to fit asset management within an agency, there are key competencies that should be established as well.

This section has three parts:

1. **Organizational Models.** How asset management functions in an agency are organized vary widely. There is no one ideal model for where to fit asset management within an organization. The right organizational model depends on a variety of factors including agency priorities, leadership locations, and TAM focus areas.
2. **Roles.** Tasks and responsibilities define the various roles that exist in a TAM program. The roles that individuals play in TAM business processes dictate how and what gets accomplished. Common TAM roles can be used to build the organizational capabilities to support a TAM program.
3. **Competencies.** When assembling an asset management team with asset management roles, an agency must consider the specific skills, knowledge, and abilities needed to successfully conduct TAM business. These competencies are the TAM organizational ingredients for delivering the TAM program.

Organizational Models

TAM organizational models help determine where to locate key TAM roles, the relationship between TAM and agency priorities, and how TAM is implemented throughout the agency. There is no one right way to locate and organize asset management within an agency. TAM is cross-cutting by nature and requires coordinated actions across planning, programming, scoping, design, construction, maintenance and operations functions.

Identifying a Home for Asset Management

There are many choices to consider when identifying a 'home' for asset management. Asset management committees can be used to achieve coordination across units, regardless of where the TAM home is located, in order to enhance the asset management culture across the organization. Some agencies choose to focus TAM activities within a single business unit and use committees and other management structures to achieve the needed coordination. Others appoint a TAM lead individual to play a coordination role with staff support and resources drawn from multiple units across the agency.

As agencies gain experience with TAM, the organizational model may evolve. At early stages of maturity, an agency may not have any organizational unit or function that is performing TAM activities. In developmental stages of TAM, an agency may create a TAM unit to signal its importance, formalize processes and integrate TAM business practices across the organization. Eventually, as TAM practice is well-established, there may no longer be a need for a TAM unit, because TAM becomes the way the agency does business. Many international agencies with mature TAM practices do not have a TAM unit.

Creating a TAM Unit

An agency can conduct an assessment of where TAM-related functions currently are by making a list of TAM roles and where they exist in the agency. This will determine if there are gaps in needed roles. It will then be necessary to decide whether TAM roles should be added to existing business units, or if it is best to have a TAM unit that performs the roles and responsibilities.

If an agency decides to create a TAM unit, the roles and responsibilities that the unit performs can initially be based on the gap assessment. A beneficial aspect of a TAM unit is that it can focus on specific activities, such as the development and implementation of a federally-compliant TAMP.

Executive Office

Placing a TAM leader or TAM unit in the executive office signals the importance of TAM to the agency and provides a close connection to agency leadership. However, the executive office typically has less direct access to technical staff support than planning or engineering units. Connections to individuals with delivery-oriented responsibilities are also less direct than they would be in an engineering or maintenance office. If the TAM unit is not in the executive office, it's important that there is an executive involved with the TAM program to both understand how TAM is benefiting the agency and to communicate the importance of TAM to the rest of the agency.

Practice Example
Building a TAM Unit in the Executive Office

Caltrans

In 2015, the Caltrans Director created a TAM lead in the agency, recognizing the importance of TAM and the necessity of having a TAM lead who is responsible for implementing TAM and meeting federal and state TAM-related requirements. The TAM lead reports directly to the Caltrans Chief Deputy Director. The TAM lead started without any staff, but the unit has grown to house over ten people. The TAM lead is a veteran of the department and is able to advance the TAM program by getting leadership commitment at the executive level and having the business units throughout the department contribute to needed activities.

Planning Office

Locating a TAM leader or TAM unit within a planning office establishes a tight connection to long-range planning and, in some agencies, project programming. This fosters a long-term view of asset investments and an integrated approach to meet preservation, safety, mobility and other objectives. However, in many agencies, the planning function is not closely connected to project selection, and may have less engineering expertise. In these agencies, planning has less influence over asset preservation investment decisions.

Engineering Office

Creating a TAM leadership position or TAM unit within an engineering office puts it in proximity to capital design and construction (program delivery) activities. This will tend to give TAM more influence at the agency, as well as access to technical staff resources. Typically, the engineering office takes care of models for asset condition (i.e. pavement and bridge management units), and optimizing asset treatment decision making. However, because of the project delivery focus, there is less connection to long-term planning, systemwide performance, or routine maintenance.

Maintenance and Operations Office

Designating a TAM leader or TAM unit within a maintenance and operations office provides a strong connection to what is happening "on the ground" with respect to asset performance. It also provides an opportunity to emphasize proactive preservation activities to cost-effectively extend the useful life of assets. However, maintenance is rarely involved in long-term planning or capital programming, so the TAM unit may have less influence on overall funding.

The practice examples below illustrate states that have TAM units in the four different agency locations. There is no one right way to locate the lead TAM unit. Figure 3.1, Locating TAM within the Agency, shows where the lead TAM unit is located in 2019 across the US states. The most commonly used location is the planning function.

Practice Examples • Asset Management Organizational Models

Executive Office Model

At Caltrans, the TAM group is in the executive office because of a desire to elevate the importance of asset management. The TAM group has more than 10 people in it who manage the TAMP development, and are also responsible for resource allocation for the State Highway Operation and Protection Program (SHOPP). The SHOPP is a ~$4B annual program for major projects on the California State Highway System (SHS).

Planning Office Model

At Michigan DOT, the asset management function is distributed across the agency, but the TAM lead is in the planning bureau. Locating the TAM lead within planning provides a strong link to strategic investment planning and decision-making.

Engineering Office Model

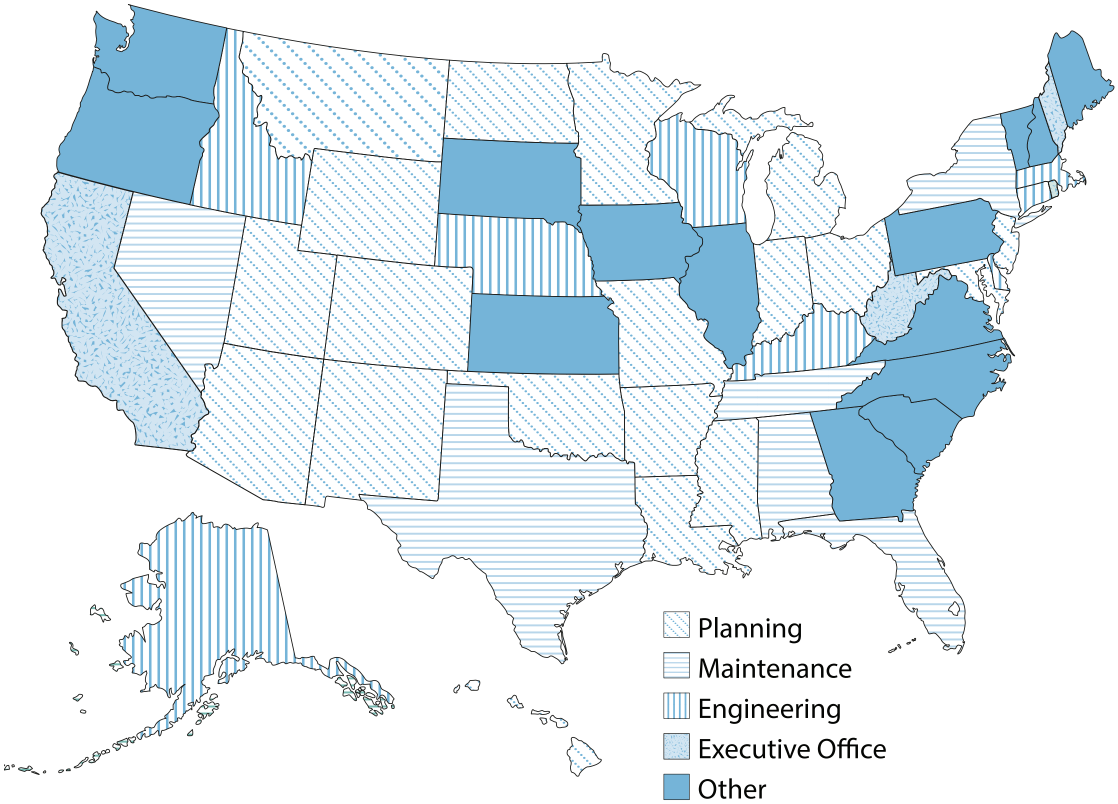
The Connecticut DOT TAM unit resides in the Bureau of Engineering and Construction and reports directly to the Office of the Chief Engineer. The TAM Unit works with asset stewards, designated for each asset, to coordinate TAM activities across the Department.

Maintenance and Operations Office Model

At the Nevada DOT, the Maintenance and Asset Management Division leads the development of the agency's Transportation Asset Management Plan (TAMP). The division supports district activities to ensure that the state-maintained highway system is maintained in a condition consistent with the Nevada DOT TAMP, work plans, policies, program objectives, budget, and available resources. It also supports a proactive preservation focus in maintenance that extends to the 10-year investment strategies outlined in the TAMP.

Figure 3.1 Locating TAM within the Agency
A Nationwide Survey

TAM involves many integrative functions that require collaboration across business units. This map shows the results of an informal survey of the location of the TAM lead within each state department of transportation.



Alabama	Maintenance
Alaska	Engineering
Arizona	Planning
Arkansas	Planning
California	Executive
Colorado	Planning
Connecticut	Engineering
Delaware	Engineering
District of Columbia	Maintenance and Operations
Florida	Maintenance
Georgia	Performance Management
Hawaii	Planning
Idaho	Engineering
Illinois	District
Indiana	Planning
Iowa	Strategic Performance
Kansas	Finance
Kentucky	Engineering
Louisiana	Planning
Maine	Performance Management
Maryland	Planning
Massachusetts	Engineering
Michigan	Planning
Minnesota	Planning
Mississippi	Planning
Missouri	Planning
Montana	Planning
Nebraska	Engineering
Nevada	Maintenance
New Hampshire	Performance Management
New Jersey	Planning
New Mexico	Planning
New York	Maintenance
North Carolina	Maintenance and Operations
North Dakota	Planning
Ohio	Planning
Oklahoma	Planning
Oregon	Engineering/Executive
Pennsylvania	Maintenance and Operations
Rhode Island	Executive
South Carolina	Performance Management
South Dakota	Engineering/Planning
Tennessee	Maintenance
Texas	Maintenance
Utah	Planning
Vermont	Independent
Virginia	Finance
Washington	Capital Program Development and Management
West Virginia	Executive
Wisconsin	Engineering
Wyoming	Planning

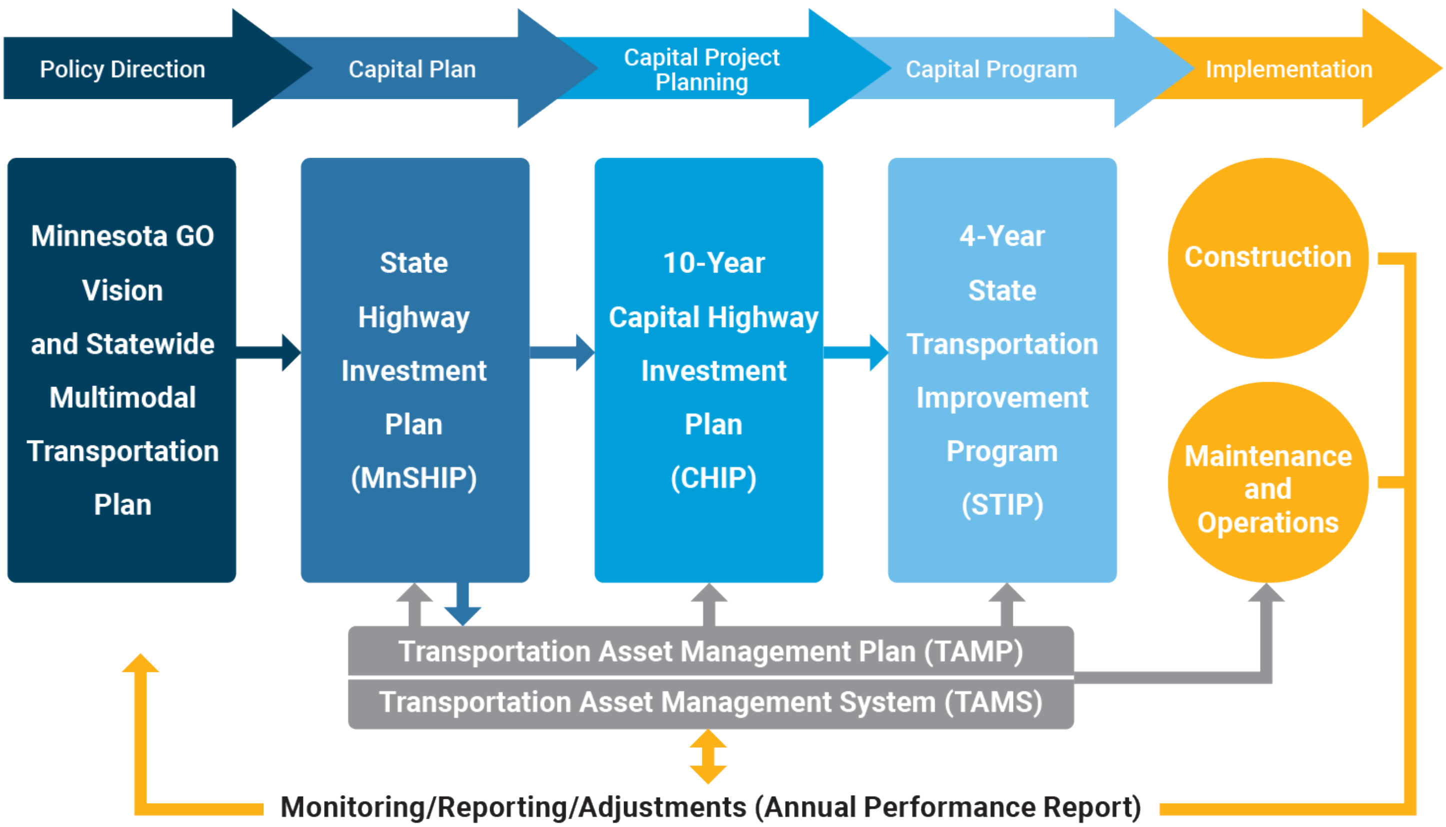
Aligning the TAM Organizational Model with Agency Priorities

The choice of a TAM organization model should align with and support agency policies and priorities. Agencies that have priorities focused on activities that are located in the planning unit (such as economic development, increasing funding, or sustainability) may choose to house TAM in planning. A greater focus on safety and rebuilding infrastructure may lead to locating TAM in engineering. Agencies that prioritize preservation and operations may choose maintenance and operations for the TAM location. Figure 3.2 Organizational Models describes how the home for TAM would work in different parts of the agency.

Practice Example • Aligning Strategy with TAM Organization

Integrating All Planning

The TAM unit at the Minnesota Department of Transportation (MnDOT) is located in the multimodal planning division. TAM is a key part of MnDOT's integrated planning process, which utilizes a framework defined with explicit coordination across plans and programs.



Source: Minnesota DOT TAMP 2019

TIP **TAM is not effective unless it is integrated with existing processes. Established agency roles in planning, programming, and delivery can support this integration.**

Figure 3.2 TAM Organizational Models
Considerations in making the choice on the home for TAM.

		Executive	Planning	Engineering	Maintenance and Operations	Field Operations
Coordination	**How do we avoid a silo approach?**	Where can the AM team best connect the functions necessary for TAM delivery such as business planning, long-term strategic planning, short-term asset planning, capital program governance, capital delivery, operations and maintenance, asset information and finance?				
Coordination	**How do we achieve consistency in decision making?**	Where do we make the majority of our asset management decisions? **Centralized.** Important that the AM Team provide connection to broader policies and leadership.			**Decentralized.** AM Team need to be well connected to Region teams. Be aware of short-term/long-term focus	
Organization	**Where is our strategic priority?**	Economic, Social, Environmental Values and Goals	Active Transport, Public Health, Sustainability	Data-driven Decision Making	Preservation Focus	
Roles	**Can we maintain a strategic focus?**	We need to avoid staff having both a governance and day-to-day management/operations roles. We need to ensure that individuals do not get bogged down with short-term issues and as a result lose sight of (and time for) longer-term strategic issues.				
Communication	**How critical is the influence on decision makers?**	Is it important that the AM team are influencing those that guide our organization (internally and externally) to ensure AM priorities are achieved? Very Important, they must be well connected			Less Important, others will help with this task	
Competencies	**Where can we attract the right people?**	Where will we be able to attract and retain individuals with the right competencies? Strategic Thinkers	Financial Analysts and Service/ Performance Assessment	Technical Analysts and lifecycle managers	Performance Assessment and improvement	
Managing Change	**Where is the right place to drive change?**	The AM Team will need to initiate, plan, implement and sustain organizational change. Resistance tends to need to understand why AM is important	Resistance tends to need to understand how AM will improve future service / planning	Resistance tends to need to understand what needs to change to create the future state	Resistance tends to need to understand how change should be implemented	

TIP **The location of TAM in your agency can evolve over time based on your needs and agency priorities.**

Centralized vs. Decentralized Models

A second important choice in creating a TAM organizational model is deciding on the degree to which asset management responsibilities are centralized versus dispersed across the agency.

Model 1. Single TAM Unit

In this model, a central office TAM unit plays a strong role in making decisions and driving TAM actions. Influence is concentrated at a single point, which has advantages, but results in less distributed ownership across the agency.

Model 2. Strong but Distributed Central Office Role

In this model, the central office plays a strong function in investment decisions, but there is no single designated TAM unit. Roles and responsibilities are distributed across multiple central office units and are supported by a central office TAM function that is tied to the investment planning role and may not have a title with TAM in it

Model 3. Central Office Coordination with Strong Field Office Role

In this model, the central office plays a coordinating role but investment decisions are primarily made by field offices. This approach fosters strong ownership and decision-making that is close to the customer. Establishment of clear guidance and standards at the central office helps to avoid inconsistencies across offices, ensures that a statewide view of asset information can be created, and takes advantage of opportunities to gain efficiencies through the standardization of tools and processes. Field units may take on varying levels of ownership for TAM with respect to data collection, condition and performance monitoring, and work prioritization. The advantage of this model is the stronger link between TAM policies, goals, and objectives and work that is implemented. The disadvantage is the lack of consistent application of TAM across the agency and the greater likelihood that non-TAM priorities are implemented.

Practice Examples
Centralized and Decentralized Agency Models

Utah DOT – Centralized TAM Unit

The TAM unit at UDOT is located in the technology and innovation branch of the agency. This unit is responsible for meeting all TAM-related state and federal requirements and more importantly for advancing TAM and performance management (PM) at the agency. Utah has a strong centralized governance approach to its management so a centralized TAM unit with emphasis on information and innovation works well for advancing TAM.

Oklahoma DOT – Decentralized TAM Implementation

The TAM unit at ODOT is in the central office under the planning unit but the implementation of TAM resides in ODOT's field units called divisions. Most decisions on asset investments and actions occur at the division-level. The central office provides data and guidance to divisions, but decision-making on assets occurs within each division. With the MAP-21/FAST requirements and the need to deliver on the two and four year pavement and bridge targets, ODOT is considering ways to strengthen the central office and division coordination.

New York State DOT – Decentralized Central Office Role

At NYSDOT, Asset Management is coordinated under the Director of Maintenance Program Planning who reports to the Assistant Commissioner for Operations and Asset Management. NYSDOT uses a committee structure, described in their TAMP, to define TAM roles and responsibilities. It has three tiers of related teams: first are the field teams who take action on assets; the next tier are statewide teams located in headquarters that provide a statewide functional team, and the top tier is a comprehensive program team that provides policy and monitoring. A diagram of this is provided in section 3.2.1.

TIP **In international agencies, outsourced maintenance is common practice. The integration of TAM objec tives in the contracts with the vendors is a important aspect of TAM implementation.**

TAM Roles

This section provides information on creating a TAM unit and describes the most common roles needed for a successful TAM program. It also describes TAM related activities within an agency that may require additional coordination. Examples of TAM roles and integrating TAM with other related agency functions are interspersed throughout the section.

Core TAM Roles

Understanding what roles and responsibilities are most important for the TAM program is key to getting an agency ready and aligned to achieve TAM-related goals. It is crucial to fill each TAM-related role with qualified people who possess the right competencies.

Three key roles provide the foundation for implementing TAM in an agency: a TAM champion, a TAM lead, and a lead for each priority asset class.

TAM Champion

Having a TAM program champion leads to greater success in meeting TAM goals and objectives. The TAM champion advocates for TAM advancement and communicates its importance throughout the agency. TAM champions can come from various groups, but they are typically senior managers or executives. The TAM champion should be able to create a vision for how TAM will deliver a stronger agency in the future, communicate how TAM can benefit stakeholders, and gain acceptance from agency staff and stakeholders.

TAM Lead

The TAM lead is the person who is the head of the TAM unit or, if there is no TAM unit, is the lead for coordinating various TAM program activities. People in this role are responsible for making sure agency staff and external partners are working together to advance TAM. The TAM lead should be a person who understands and can manage dependencies across activities and who can develop and maintain good working relationships. The TAM lead should be a constructive problem solver who can monitor the entire program, spot concerns, and listen to and consider alternative points of view when necessary.

An agency's top management support is an key component of TAM success. One important role of the TAM lead is to keep executive management informed about and engaged in the TAM program. This requires regular and effective communication with executives about plans and achievements. Building executive support for and confidence in TAM activities helps to ensure continued resources and support for TAM activities. When the rest of the agency sees executives supporting the TAM program, they are more likely to assist with TAM needs.

Asset Stewards

Asset stewards (sometimes called "Asset Owners," "Asset Managers" or simply "Asset Leads") have lead responsibilities for managing a particular class of asset. This role can be assigned at the agency-wide level as well as at the field office level. An asset steward should be someone who understands the asset well, has the ability to communicate the asset's needs and the consequences of underinvestment and is able to work with other asset stewards to develop agency-wide investment strategies.

Practice Examples
Leadership Vision

Iowa DOT

When the Iowa DOT TAM program was established, agency leadership prioritized the creation of a world-class asset management program and decided to address TAM implementation as a top-level organizational change initiative. This leadership focus and support allowed Iowa DOT's TAM team to have authority throughout the agency, address organizational improvement needs, and focus on sustainability by building TAM governance.

TAM-Related Functions: Planning, Programming, and Delivery

TAM is inherently an integrative function, so designation of individuals performing key roles within agency planning, programming and work delivery functions can clarify the key points of responsibility and foster cross-functional coordination.

Project Prioritization

Within each program, key actions include:

- Adopting and modifying policies and guidelines for how and when prioritization is done
- Developing prioritization methodologies
- Coordinating the execution of the process
- Gathering and compiling data
- Implementing, managing and updating information systems to support the process
- Performing analysis for individual projects
- Analyzing, reporting and communicating prioritization results
- Making final decisions about which projects will be advanced for funding

Maintenance and Operations

When work is being conducted in the field the following are important considerations for TAM program support:

- Understand TAM goals and objectives and how field actions impact end results.
- Understand the choices made during the programming process on asset treatments.
- Capture data on work accomplished data to keep asset information accurate.
- Train field staff on the TAM program

Data Collection

Several steps are required to plan and execute data collection efforts – and then to process and store the data that are collected. Some agencies have established roles to provide standardization and coordination across data collection efforts. For each effort, key roles include:

- Analysis to provide a sound business case for data collection
- Research to identify the best method and approach to collecting the data
- Procurement – when contractors are used to collect data
- Data specification and design – that considers integration with existing agency data
- Hardware and software specification and acquisition for data storage and processing
- Guidance and oversight to ensure consistent and valid data
- Data quality assurance
- Data loading and validation

Development of a Long Range Plan

The long-range plan sets the framework for impactful asset investment decisions for the rest of the transportation development process. TAM implementation has a greater impact if TAM roles and responsibilities are clear in this step. It is also important to determine who will take the lead for the following:

- Long range plan policies and priorities related to TAM
- Consideration of tradeoffs across investment types (all program areas and across asset classes)
- Consideration of TAM investment distribution within asset classes (rebuild, rehab, preservation)
- Financial planning (funding outlook across investment types)

Program-Level Budgeting

Allocation of resources across program categories is a critical decision that both enables and constrains what can be accomplished. Where programs are defined based on funding sources or where allocations are based on formulas, there is little or no flexibility. However, where there is flexibility, it is important to establish TAM roles for technical analysis of investment versus performance tradeoffs, as well as for orchestration and facilitation of tradeoff decision making based on the results of this analysis.

Practice Example
TAM Project Prioritization

Wyoming DOT

WYDOT is increasing the use of performance-based project selection in order to optimize funding expenditures and meet their performance targets. This process helps guide resource allocation decisions in a constrained funding environment. WYDOT adopted a robust computerized system that moved the agency from project selection predominately based on emphasizing current condition to project selection based on optimizing future estimated condition. Program managers for each asset type are responsible for maintaining their individual management systems in order to make performance forecasts within their program areas. The TAM lead works with the program managers to get the guidance to the districts. The TAM lead has been working with districts to build confidence in the management system outputs and the decision-process. This improvement has yielded WYDOT's ability to deliver the targets that they project.

Development of the TAMP

TAMP development is a multi-step process that involves agency stakeholders. Clearly articulating process, roles, and lead responsibility for the document yields the best product and makes it easier to implement the TAMP. Table 3.1 illustrates how to provide the link between roles and the key components of a federally-compliant TAMP development process.

Table 3.1 Links to the TAMP Development Process

TAMP Component	Example TAM Roles and Responsibilities
Asset Inventory and Condition	**Data Collection:** State NHS (asset owners); Local NHS (bridges: state bridge unit, pavements: individual local agency data collection units) **Data Management:** State DOT planning unit collects all data from the various data collection leads **Reporting and Visualization:** TAMP development team
Asset Condition Forecasts	**State System** **Bridges:** State bridge management unit runs bridge management system (BMS) **Pavements:** State pavement management unit runs pavement management system (PMS) **Other Assets:** No management systems exist for the other assets so each asset owner uses ages to forecast asset condition in the future **Non-State NHS** **Bridges:** State bridge management unit runs bridge management system (BMS) and provides forecasts for the entire NHS **Pavements:** State pavement management unit uses the data collected from local agencies runs pavement management system (PMS) and provides forecasts for the entire NHS
Financial Planning	**State Funding Forecast:** State Chief Financial Officer (CFO) **State Funding Uses:** TAM unit works with CFO, programming unit, and asset owners to determine uses **Non-State NHS:** TAM unit works with MPOs and local agencies to determine both funding forecasts and uses of funding
Life Cycle Planning and Management	**State Assets:** TAM unit takes the lead in developing agency wide asset life cycle management policies. Each asset owner uses the agency wide policies and works with the field units to determine asset specific policies. **Non-state NHS Assets:** Local agencies are invited to a workshop to provide input on life cycle planning and management policies impacting their system. This input is used for development of non-state owned NHS policies.
Risk Management	The TAM unit organizes a workshop to develop and refine the risk register and to develop risk mitigation actions. **State Assets:** Information is used during the programming process to determine funding for risk mitigation actions. **Non-state Assets:** For non-state NHS bridge and pavement assets, MPOs and local agencies are invited to the risk workshop to participate in the development of the risk register and mitigation actions. Specific funded initiatives are reported by the MPOs and local agencies to the TAM unit for inclusion in the TAMP.
Investment Strategies	The TAM unit works with individual asset owners and field units to prioritize investments for TAM improvements, and to meet TAM targets and forecasts. MPOs work with local agencies to develop investment strategies to advance NHS pavement and bridge performance.
Process Improvements	The TAM unit uses a workshop to bring together all stakeholders to develop and prioritize TAM improvement initiatives.

TIP A TAMP cannot be developed in a silo; it required input from across the agency. See Chapter 2 for more information on TAMP development.

Supporting Roles

The following additional roles are important to support TAM in an agency:

Asset Data Stewards: ensure all data related to a specific asset class is accurate and aligned with other pieces of data; this is not the same as asset steward/owner

Asset Management Software System Owners: manage/own specific software systems, bridge/pavement management system; the owner is the software owner.

Asset Management Software System Architects: look at the connectivity of information across systems and across outputs.

Analysts (data, economics, financial): take data, then apply statistical, economic or financial analysis to provide guidance using that information.

Maintenance and Operations Managers: are out in a district or field office managing the day-to-day asset activities.

Environmental Specialist: assess asset vulnerabilities due to extreme weather events and propose mitigation actions.

IT and Data Specialists: usually reside in the Data/IT unit; ensure that overall information and tools support asset management work.

The following disciplines are key components of a TAM program:

Engineers: apply understanding of specific asset types, how the condition and role of assets influence treatment choices, and model how investments influence future performance.

Planners: in the planning or other units; consider long-term planning/policy-making for asset as it relates to programming and the connectivity of information throughout the cycle of activities.

Economists: look at economic tradeoffs of various scenarios on actions taken for a specific asset.

Building a Strong TAM Team

Matching TAM Roles to Skills

When TAM is first initiated, roles can be filled with available staff in a manner that takes advantage of available talents and personalities:

- **TAM Lead:** people-oriented and enthusiastic, able to manage conflict across business units.
- **Resource Allocation Leads:** analytical and proficient with complex software.
- **Data Collection & Management:** detail-oriented and accurate.

Practice Example
TAM Maintenance and Operations

Virginia DOT

The Virginia DOT maintains most of the assets on state roads. For pavements and bridges, there are asset leads at both the central office and in the districts. Asset leads at the central office manage data collection 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. The guidance on what work will be done varies by asset class. For overhead sign structures, both the district structure and traffic lead are involved with guidance from the central office traffic engineering division.

Table 3.2 Agency roles list and location

	Executive	Planning	Engineering	Maintenance & Operations
Policy Making	●	●	●	
Asset Owner		●	●	●
Asset Data Steward		●	●	●
Asset Software		●	●	●
Asset Engineer		●	●	●
Economist		●		
Finance/Funding	●	●		
Field Manager				●
Communications	●	●		●

TIP TAM is a team effort requiring involvement from analysts, managers, and to executive leaders.

- **Field Maintenance Management:** task-oriented monitors.
- **Prioritization Leads:** comfortable with uncertainty (gray areas), and willing to make decisions.

Agencies have different skill needs and capabilities. Some agencies might possess skills ideal for one part of the TAM program, while it might be necessary to look outside the agency (outsource) for other skills. Outsourcing can be pursued to address a vacancy for a highly qualified position, or to make up for the lack of a specific skillset in the agency.

Making the Case for TAM Positions

Building a case for TAM positions requires defining how the gaps in staffing will hold the agency back from achieving its objectives. If possible, describe the anticipated return on investment from the added staff. It can also be helpful to evaluate TAM efforts at peer agencies, to find out if they have a TAM unit, how many people are in it, and what roles and responsibilities they have. Find examples of agencies that successfully made the case for new staff positions and borrow from their approach.

A Forward-Looking Approach

Part of building a strong TAM team is seeking skills that will help to advance practices rather than sustain the status-quo. Advancements in technology are changing the way data are collected, processed and analyzed; and how work is planned and carried out. As automation increases, certain routine tasks become obsolete, while it becomes necessary to acquire new skills to take advantage of improvements. For example, with tools that produce more robust analysis, agencies will need less people who crunch the numbers but more people to interpret and communicate the results.

Typically, when an agency starts its TAM journey, data accuracy is an issue. When data is not accurate, people may lack the confidence necessary to use the data for making decisions. As data quality and availability improve, the TAM program develops a need for stronger data analytic skills.

As processes become more complex, new skills are needed to monitor and carry out checks and balances. TAM aims to cut across traditional silos, which gets complicated as more units and stakeholders get involved. Therefore, TAM units benefit from people who are comfortable dealing with complex processes. This is a capability that can be acquired through hiring or training.

Practice Example
Skill Building Through Training

Utah DOT

The Utah DOT has a strategic initiative to build a learning organization. A key element of this is a learning portal that includes training components. The training components include role expectations, guidance on how to fulfill key responsibilities of the role, and certification information. They have implemented modules for first time supervisors, transportation technicians, stormwater management and advanced leadership with more being developed monthly.

Checklist

TAM Roles

Agencies can use this checklist to determine if there are any gaps in the roles needed for a successful TAM program. These roles may be performed elsewhere in the agency, but may not be formally linked to the TAM program. If this is the case, an agency needs to formally establish the roles as TAM-related. If there are no existing staff to fill the necessary TAM roles, the agency may be able to make a case for new positions or outsourcing. Identifying how lack of appropriate skills will keep the agency from achieving goals, the anticipated return on investment from TAM, or comparison to TAM implementation at successful peer agencies can help make a case for additional staff or outsourcing.

- ☐ **Asset Management Lead(s).** Responsible for implementing TAM and meeting federal and state TAM-related requirements.
- ☐ **Asset Owner (also called asset steward).** Has lead responsibilities for managing a particular class of asset. Can be at the agency or field office level.
- ☐ **Asset Data Steward.** Ensures all data related to a specific asset class is accurate and aligned with other pieces of data.
- ☐ **Asset Management Software System Owner.** Manages specific software systems, bridge/pavement management system.
- ☐ **Asset Management Software System Architect.** Looks at the connectivity of information across systems and across outputs.
- ☐ **Asset Engineer.** Applies engineering know-how to specific asset types.
- ☐ **Analyst (data, economics, financial).** Takes data, then applies statistical, economic or financial analysis to provide guidance using that information.
- ☐ **TAM Planner.** In the planning or other units; considers long-term planning/policy-making for assets as it relates to programming.
- ☐ **TAM Programmer.** Considers program-level investment decision-making for assets.
- ☐ **TAM Economist.** Looks at economic tradeoffs of various scenarios on actions taken for a specific asset.
- ☐ **TAM Field Manager.** Manages day-to-day asset activities in a field/district office.
- ☐ **Environmental Specialist.** Assess asset risks and vulnerabilities from extreme weather events.
- ☐ **TAM IT and Data Manager and Specialist.** Usually in a Data/IT unit; ensures overall information and tools support for asset management work.

Competencies

Competencies are the combination of observable and measurable knowledge, skills, abilities, and personal attributes that enable individuals or groups to successfully perform their roles and responsibilities. Successful asset management requires a mix of technical and non-technical competencies.

Part of building a strong TAM team is seeking skills that will help to advance practices rather than sustain the status-quo. For example, implementing a TAM program relies on data accuracy and strong data analytic skills. Typically, when an agency starts its TAM journey, data accuracy is an issue. When data is not accurate, people may lack the confidence necessary to use the data for making decisions.

Advancements in technology are changing the way data are collected, processed and analyzed, as well as how work is planned and carried out. As automation increases, certain routine tasks become obsolete, while it becomes necessary to acquire new skills to take advantage of improvements. With tools that produce more robust analysis, agencies will need fewer people who crunch the numbers but more people to interpret and communicate the results. As processes become more complex, new skills are needed to monitor and carry out checks and balances. TAM aims to cut across traditional silos, which gets complicated as more units and stakeholders get involved. Therefore, TAM units benefit from people who are comfortable dealing with complex processes.

Key Competencies

Successful TAM practice relies on a number of key competencies:

Leadership: ability to establish a vision and motivate others to work towards achieving that vision.

Management: ability to make sure that the multiple activities in a TAM program are planned, coordinated, aligned and tracked.

Engineering: ability to understand the fundamentals of transportation asset and system design, construction, maintenance and operation.

Environmental: ability to analyze/ develop prediction models to measure how environmental changes may impact highway infrastructure

Financial planning: ability to understand financial planning basics and an awareness of funding sources and financial tools

Planning: ability to understand a DOT planning process and the constraints of that process.

Strategic planning: ability to understand strategic planning and how TAM fits into an agency's business activities.

Problem solving: ability to work through inevitable conflicts and issues that arise in the process of working across agency silos.

Relationship building: ability to get different units in an organization to collaborate.

Analytical capabilities: ability to design and apply appropriate methodologies to gain key insights from available information.

Computer know-how: ability to work with a variety of software and comfortably navigate common operating systems.

Data know-how: ability to understand data structures, assemble and manipulate data in a variety of formats, and assess data quality.

Communications: ability to keep communication in forefront of everything that's done; always aiming to make others understand what TAM program is trying to do. This is important when convincing individuals of

Practice Example
Building Competencies

FHWA/AASHTO Peer Exchanges

FHWA, in partnership with AASHTO, has held an annual TAM peer exchange since 2007. These peer exchanges have been a good forum for state DOT representatives to meet each other and hear practices related to the topic of the peer exchange. Peer exchange not only share key ingredients of successful practice – they also discuss challenges and obstacles. The peer exchanges are documented in published reports that are available to the public. A valuable aspect of the peer exchange are the relationships that are formed so that informal exchanges can occur throughout the year.

TIP A key requirement under ISO 55001:2014 Asset management is ensuring the organization has identified competencies and is able to demonstrate their staff meets them.

change, or helping stakeholders understand TAMP long-term deliverables.

Positive Attitude: in large-scale organizational change, taking a positive attitude is crucial to having people accept the change that will help strengthen the program, and convincing them that the solutions are the right ones.

Developing Competencies within the Organization

Peer-to-Peer Learning

TAM knowledge and skills can be gained through experience and peer to peer (P2P) learning. Peer exchanges sponsored by national organizations such as FHWA, FTA, AASHTO, and TRB can be crucial to cross-fertilizing knowledge and experiences. At these peer exchanges, individuals can meet peers and build relationships that they can rely on as issues arise in implementing TAM. There are also TAM-related conferences, such as the TRB TAM conference that is held regularly. In addition, asset-specific conferences and TAM workshops are held regularly. Many times, these events are by invitation, so agencies should contact AASHTO and FHWA to find out about upcoming events.

Competency Assessment & Training Tools

The Institute of Asset Management (IAM) offers an asset management certificate for those who are beginning in TAM roles. The certificate validates a basic understanding of TAM within seven discipline areas and leads to an IAM diploma.

The National Highway Institute (NHI) offers numerous training courses to help build and develop skills in TAM. Some courses are instructor led, others are web-based. Courses are available for all levels, from those just starting in TAM to those who want to develop greater expertise and to help take their TAM programs to the next level of maturity. In addition, transportation professionals can use many of the courses to obtain Continuing Education Units, Certification Maintenance credits, and Professional Development hours.

AASHTO and FHWA are continuously developing new capacity-building resources so stay tuned for new training tools.

Information Sharing

When thinking about which competencies are needed in an agency's TAM program, it is helpful to look at job descriptions for TAM positions in peer agencies. This includes new job descriptions that are developed for emerging roles, such as data scientists. AASHTO is building this capability to share job descriptions. Go to the AASHTO TAM Portal to access this resource.

Consultants

When a TAM unit finds it hard to acquire a core TAM competency, it may be necessary to hire a consultant to fill the need. Consultants can be considered when:

- There is a need to perform a specialized task on a one-time or relatively infrequent basis
- The types of competencies required are difficult to obtain in the marketplace (e.g. data science)

It is important for agencies to clearly define what they hope to gain from consultants beyond delivery of a report or system. Consultant engagements can be designed to build in knowledge transfer activities to add needed competencies in house.

Changing Job Market

In the current robust economy, new employment opportunities make it difficult for state DOTs to attract and retain talent. Developing your TAM organization model to accommodate shorter tenures, incorporate knowledge management, and be clear about the relationship between roles and their impact is important to continued success of the effort.

Finding Talent

Agencies can consider converting existing staff with a planning, financial, or engineering background. Candidates must be results oriented, able to communicate well, possess good presentation skills and be able to bring diverse people together for common goals.

Practice Examples Competencies and People

New Mexico DOT

The Capital Program and Investment Director led the NMDOT Asset Management effort and has spent her career in transportation, starting at the FHWA before moving to NMDOT. She has worked in engineering, administration, and as a district engineer at NMDOT. This variety of experiences gives her the competencies needed to be a successful TAM lead.

Minnesota DOT

The TAM lead at MnDOT came to the role from the maintenance side of the agency. The experience and understanding of maintenance business processes, data needs, and organizational culture help him lead and manage the implementation of TAM processes. Having direct responsibility for budgets and workplans related to maintenance assets, as well as experience in setting statewide performance measures for maintenance services, provided valuable skills and knowledge that now help him to deliver the TAM program at MnDOT.

Connecticut DOT

The CTDOT TAM data lead started his career in CTDOT's bridge design unit and moved his interest to the architecture, engineering, construction applications area. The competencies he has built in IT and data combined with his business understanding of transportation assets are important in helping CTDOT's TAM program roll out tools that support TAM decision-making. The roll out of these tools is in parallel to capital project delivery enhancements that produce continued efficiencies for the entire delivery team.

TIP A job description portal is a part of AASHTO s Organizational Capabilities Management Portal. This is an excellent tool for sharing TAM job descriptions and competencies information.

How-to
Recruit Individuals for Asset Management Roles

Getting an asset management program off the ground or increasing the maturity of an already existing program may require recruiting individuals to fill specific roles. Recruiting can be undertaken by the TAM champion, TAM lead, or other individuals invested in the success of the TAM program. This How-To Guide describes five steps to help the recruiting process go smoothly and effectively meet the needs of the agency.

Recruiting for TAM Roles

1. Determine the roles needed in the TAM program
2. Determine the competencies needed
3. Determine internal or external candidate
4. Develop role descriptions
5. Advertise and fill

1. Determine the roles needed in the TAM program

Agency staff can use the list of TAM roles and the checklist on the next page to assess the needs of the asset management program.

2. Determine the competencies and desirable attributes for the particular roles the agency aims to fill

Note that all positions do not require all competencies. Agencies can narrow the list to the specific competencies required for the roles available.

3. Determine if the role should be filled by someone internal or external to the agency

Looking at the list of competencies and desirable attributes, is it possible to convert someone from a different area of the agency to fill the role? Can an external, new individual learn on the job or does the role require particular skills and knowledge from within the agency? Alternatively, can the role be filled by a short-term consultant? Note that the missing role may already be done by people in the agency, but perhaps without an explicit connection to the TAM program or group. In this case, these individuals should be formally included as part of the TAM team, but may not need to change departments or jobs.

4. Develop role descriptions

Agencies should consider what asset managers value in a place of work and incorporate these into the descriptions. The job description should attract the type of person the agency is ultimately looking for, so including information on the competencies and desirable attributes is key. Agencies can utilize the job descriptions available on the AASHTO Organizational Capabilities Management Portal that was developed through NCHRP 20-24(95) for TAM-related positions. If an agency develops new descriptions for positions, it can in turn share these through the portal.

5. Advertise the role and fill the need

An agency can recruit internally, advertise the role with external networks, or hire a consultant to fill the need. It is important to convey the overall mission or goal of asset management for the agency. If filling the need simply means making an explicit connection between asset management and a function already performed within the agency, then it is important to convey to the individual how their work impacts the asset management program processes.

TIP **Existing employees in an agency can be identified to build TAM competency. There are training oppor tunities in different TAM topics hosted by TAM organizations identified in Chapter 1.**

Section 3.2

Strengthening Coordination and Communication

Coordination and communication are key ingredients for TAM success. Many aspects of TAM require alignment across a diverse set of business units and external stakeholders. The goal of coordination and communication is to bring people and groups together to achieve a common set of goals.

This section has three parts:

1. **Internal Coordination.** TAM involves ensuring different parts of an agency work together to make better resource allocation decisions.
2. **External Coordination.** Various external entities have a role in TAM and require coordination to deliver the best results.
3. **Communication.** Strong communication helps TAM programs progress and maintain awareness within an agency.

Internal Coordination

Different business units in an agency contribute to the TAM process and are crucial to its success. Many TAM activities depend on internal agency coordination, including: drafting TAM policies that impact units throughout the agency; establishing performance targets for asset condition; developing the TAMP; and prioritizing projects and initiatives. The agency's planning, programming, project development and delivery, maintenance, and other units must coordinate to make TAM work.

TAM-Related Committees

This section touches on the importance of internal coordination committees across the various TAM-related activities. The form of committees is directly related to the agency's organizational model. These coordination committees are focused on coordination across functions. The coordination committees with important roles in TAM decision-making include:

TAM Steering Committee

This is a senior-level committee made up of top decision-makers. They provide strategic oversight for TAM and facilitate resourcing and organizational support for agreed-upon changes. They also make sure that the politics of any decision are considered. The How-to Guide Establishing a TAM Steering Committee provides steps to set up this function.

Asset Stewards Committee

This is a committee consisting of individuals with accountability for different assets. It provides a forum for getting agreement on standardized approaches enabling a holistic view of the TAM program, communication about management practices, and discussions about coordinating project development and work planning.

Asset Data Governance Committee

This committee focuses on improving data for TAM. Its activities may include: coordinating asset data collection activities; developing standards to enable integration of data about different assets; monitoring and facilitating adoption of existing standards; establishing data quality management processes; and advancing investments in tools for field data collection, data analysis, reporting, and visualization.

TAM Working Group

This group is composed of unit managers across the agency who deal with key aspects of the TAM process – planning, programming, delivery, maintenance, data management, communications, etc.

Coordinating across TAM committees is also an important function. Typically the TAM lead will make sure the activities of various TAM committees are coordinated. In some agencies, the governance across the committees are explicitly stated so that everyone understands who is doing what and how decisions across committees are related.

Practice Example
Developing a TAM Steering Committee

New Jersey DOT

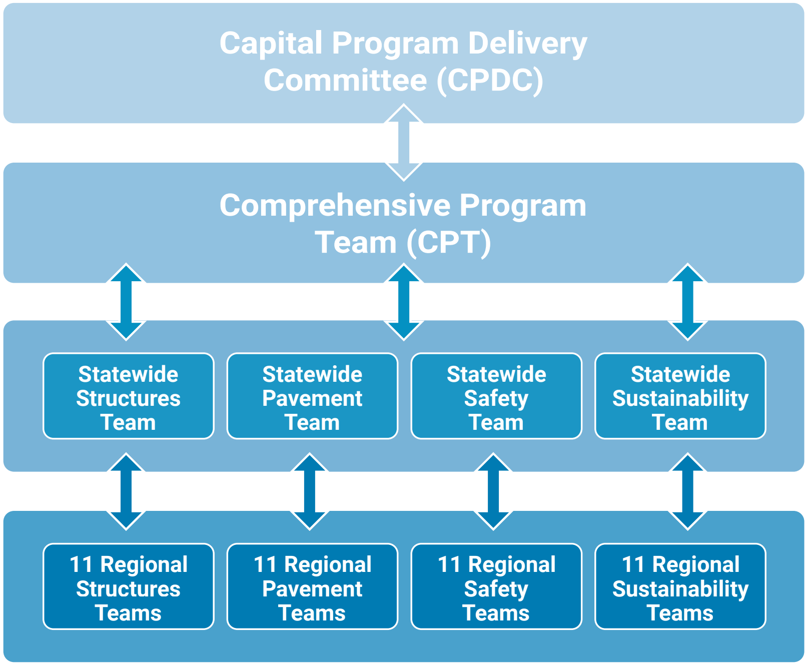
The New Jersey DOT TAM Steering Committee is comprised of NJDOT senior leadership. The committee sets policy direction and provides executive oversight for the performance management of the state highway system. The Transportation Asset Management Steering Committee provides general direction to the TAMP effort and assists in communicating the purpose and progress to other stakeholders.

TIP Forming a new set of committees to provide TAM coordination is not always the best approach. Some agencies can rely on their existing management structures. Others may already have committees set up to facilitate cross unit communications. Smaller agencies may be able to rely on informal communication. What is most important is that the TAM program gets the results it seeks.

Practice Example
TAM-Related Teams (committees)

New York State DOT

NYSDOT's TAM program is made up of a set of teams that perform TAM-related activities. They use TAM as an all encompassing set of principles that are embedded in activities they perform to make and deliver investments that provide mobility and safety to the traveling public. The TAM program coordinates inside the agency to ensure that TAM is being implemented as efficiently and effectively as possible. The following diagram illustrates the inter-relationships and communication that occurs across functional and geographic teams to make TAM work.



Source: Adapted from New York State Transportation Asset Management Plan. 2018

Practice Example
TAM Data Collection

Ohio DOT

The Ohio DOT Asset Management Leadership Team is a cross-disciplined team with representatives from all major business units, that establishes data governance and data collection standards. The TAM Audit Group, a subgroup of the Asset Management Leadership Team, is responsible for overseeing all asset data related requirements and making sure departmental data standards are in place and organizational processes are followed. This group reviews and approves all data collection efforts and ensures that efforts are coordinated across the DOT. Having designated roles and responsibilities in regard to data governance and data collection allows the agency to identify all potential customers of the data being collected and ensures that the data is sufficient to meet all relevant asset management needs.

The Ohio DOT deploys a hierarchy for managing TAM data collection.

- TAM data priority is established by the Governance Board (Assistant Directors)
- The Asset Management Leadership Team (AMLT), which is a cross-discipline team of representatives from all major business units, develop strategies and collaboration opportunities to achieve Governance Board directives
- The TAM Audit Group (TAMAG) perform business relationship management by working with data business owners, SMEs, and stakeholders to create enterprise TAM data requirements
- The Central Office GIS team utilizes the completed TAMAG business requirements to create data collection solutions
- The District TAM Coordinators provide oversight, support and coordination for data collection solution implementation, operations and performance

How-to

Establish a TAM Steering Committee

A TAM Steering Committee can help provide strategic level oversight and facilitate resourcing for TAM. This How-To Guide provides four steps on assembling a committee and getting it off the ground.

1. Determine the scope and objectives of the committee

What is the goal and mission of this committee? What specific objectives should this committee accomplish throughout the year? Use the TAM program goals and objectives to support this activity.

2. Select the members of the committee

Typically, steering committees are made up of executive and senior leadership. Consider who should to participate in the steering committee and what the role of each individual member should be. Also consider what specific influence is needed to accomplish the objectives established in the first step. Does the agency need people with decision-making authority? Does it need people with the ability to follow-though on policies and initiatives? Should you have outside partners represented, for example the FHWA Division TAM lead?

3. Determine meeting schedule and specific tasks

This step should determine the frequency of committee meetings, taking into account the availability of the members selected to participate. It should also determine the specific tasks the steering committee should accomplish, especially in the first few meetings. Having meetings too frequently may impact participation. Having meetings too infrequently may slow TAM progress.

4. Develop a steering committee charter

It is necessary to document all the information about the steering committee in a charter. The charter should include at a minimum: scope and objectives, members, roles, and a meeting schedule. Sometimes a charter is created first. If this is the case, the steering committee should review and edit the charter so that they own the responsibilities.

5. Develop a communication plan

This activity will focus on how the steerings committee communicates with other committees and with agency leadership. It should articulate a regular reporting schedule and how best to ensure that reports get the necessary attention to advance TAM.

TIP When forming a committee, it is important to limit the overall size of the committee to the smallest group needed to accomplish its objectives. Common practice is to limit committees to no more than 12 members.

External Coordination

In order to deliver transportation products and services to the public, State DOTs must coordinate with other agencies that own and operate transportation facilities. Users don't distinguish who owns what part of the transportation network, so it is up to the agencies to work together and seamlessly deliver the best results to users.

External Entities

Many entities outside of a state DOT are part of the TAM advancement process. It is important to include external partners in TAM committees. For example, many agencies will have a FHWA member on the steering committee, or a governor's representative on the strategy committee.

Metropolitan Planning Organizations (MPOs)

MPOs carry out transportation planning processes and represent localities in urbanized areas. MPOs are mandated and funded by the federal government and help ensure that transportation planning in the region reflects the needs of the population. MPOs may be responsible for parts of the State's NHS. It is a federal requirement to involve MPOs when planning or programming federal aid in metropolitan areas, so it is key to coordinate with these organizations when developing the TAMP.

Local Agencies

Local agencies include city and county agencies. These agencies have a stake in asset management initiatives as they often own various parts of the transportation network and have funding for transportation projects. They are also closely connected to the population in the region and thus have an understanding of the needed asset management-related investments.

Other State Agencies

Various aspects of asset management should include other state agencies. State environmental agencies can provide guidance on air quality and emissions. State information systems agencies can be important for obtaining tools or solutions on a TAM need. Statewide data management initiatives may also require close coordination between the state and the DOT.

Toll Authorities

Toll Authorities operate toll roads across the country to generate revenue for use in maintaining the road. Depending on the relationship between the DOT and the authority, the authorities may own the road, have data and information on the condition of the road, and information on the investment in maintenance over time. It is key to coordinate with the authority to obtain a complete picture of the assets in the state.

Other Modal Agencies

Other Modal Agencies include organizations that operate transportation modes that are not directly operated by the state DOT. These might include public transportation, airports, and marine-related functions. The DOT may have a financial relationship with these agencies for grant-related funding. The DOT will also work with these organizations to deliver the best trip for a traveler.

Practice Example
Statewide Coordination

Michigan DOT

One way to coordinate and collaborate across external agencies is to establish a statewide council.

Michigan's Transportation Asset Management Council (TAMC) coordinates TAM at the statewide level. It consists of 10 voting members appointed by the state transportation commission. The transportation asset management council shall include two members from the County Road Association of Michigan, two members from the Michigan Municipal League, two members from the state planning and development regions, one member from the Michigan Townships Association, one member from the Michigan Association of Counties, and two members from the Michigan Department of Transportation. (https://www.michigan.gov/tamc). In addition, Michigan formed the Michigan Infrastructure Council to: coordinate work beyond transportation assets such as water and communication assets; develop the statewide asset management database, and facilitate the data collection strategy for assets. (https://www.michigan.gov/mic/)

TIP **A Memorandum of Understanding (MOU) is an informal agreement on coordination between agencies or other organization. They are effective in clarifying roles and responsibilities between the two agencies and de termining how decisions will impact business in the future. For example, informal data agreements often specify who is collecting what, how data is being provided, and what geographic network is included.**

Legislative and Oversight Bodies

The governor, transportation commission, and state legislative bodies help determine the funding allocations for each state. It is good practice to coordinate with these entities to ensure they understand the importance of asset management and the need for continued DOT funding.

USDOT and its modal agencies such as FHWA, FTA, and FAA also play a role. The FHWA has state division offices that are the conduit through which states receive federal funding.

Cross-Agency Committees/Councils

Most states have a complex network of agencies that own pieces of the road network in the state. Having a committee or council focused on coordinating TAM policies, pooling resources for tools and methods, and sharing lessons learned can increase the efficient delivery of transportation to customers. This approach can work for geographic regions that cross state boundaries.

General Public

DOTs work with the general public during the planning, programming, and project delivery process. The general public represents the customer that the DOT is ultimately serving with its transportation products and services.

Stakeholder Engagement

Stakeholder engagement is another mechanism for coordination. External stakeholders can be partners the agency works with to deliver TAM benefits, and they can also be customers who use the transportation system. Keeping stakeholders informed and engaging them to understand TAM can lead to their support for funding initiatives and their understanding of tough decisions where services may be cut.

Communities of Practice

Communities of Practice (COP) can be used to coordinate with external stakeholders and partners. For example, these communities could be organized across the various asset owners within a region or state to achieve a comprehensive view of TAM. This is a good way to meet MAP-21 requirements and communicate a view of the NHS.

Practice Example
Community Engagement

New Zealand Transport Agency

Many non-United States organizations have integrated asset management not only within internal organization processes, but also in frameworks that integrate external expertise to assist in infrastructure management. The New Zealand Transport Agency clearly establishes the roles and responsibilities of agency stakeholders and documents the annual transportation planning processes and management practices it employs. This helps the agency manage and deliver the road network, add transparency, and allow resources (other levels of government, consultants, contractors, and other stakeholders including the public) to participate in the process. In this way, it integrates internal and external coordination between stakeholders in the asset management process.

Practice Example
Transportation Commission Engagement

Colorado DOT

The CDOT TAM and Performance Management unit works very closely with the Colorado Transportation Commission, which represents all of the geographic regions in Colorado. Each member of the commission is appointed by the governor and confirmed by the state senate. The commission meetings are open to the public so that all customers of the state's transportation system are welcome to attend. This promotes participation and transparency between the DOT and its customers. The meeting agenda and materials are available on a website that CDOT manages (https://www.codot.gov/about/transportation-commission/). In the past, the Commission had a designated TAM subcommittee, but due to the prioritiy of TAM, it is now an integral part of the full Commission's regular business and no longer a subcommittee.

TIP Public Private Partnership (P3) Concessionaires are entities that are much more common in interna tional settings. They are not used extensively in the US. When they are involved, it s important that the performance measures that are being applied to them match the TAM policies and procedures.

Communication

Strong communication helps TAM implementation programs progress with momentum and helps maintain awareness among all stakeholders. This includes the production and delivery of strong communication products that highlight TAM performance and benefits. An agency should consider a variety of tactics to communicate effectively on all fronts.

Formal and Informal Communications

Agencies with well-planned communication strategies tend to employ a range of techniques to successfully advance TAM awareness and knowledge-sharing. These techniques can be categorized broadly into two groups, formal and informal communications, with distinct characteristics.

Formal communication often provides the stimulus for informal communication. Communication strategies for TAM programs that embed aspects of both types of communication tend to be more successful. Understanding the relative importance of both communication types is important in promoting awareness and knowledge about TAM within an organization.

Communications Mechanisms

Audience-Centric Communication

Holistic communication is about understanding and structuring communication to achieve the best results. This is not always an easy proposition, as effectively communicating a message can be described as changing another person's perception of an idea. One of the keys to successfully getting desired communication results is knowing the target audience and providing the right communication mechanism.

Mechanisms

There is a broad range of communication mechanisms available for use, and selecting the right one will increase the likelihood of success. Once the audience is identified it is worthwhile to consider the communication style that the audience would best respond to (verbal, experiential, visual or written), what media or social media platforms they have access to, and whether an interactive environment is appropriate.

Practice Example
Strategic Communications

Utah DOT

When meeting with legislators, the UDOT CEO uses the agency's Strategic Directions Dashboard to communicate TAM-related information. He is able to quickly respond to questions and show information in a way that is easy to understand. The dashboard shows how UDOT is investing funds allocated by the Utah State Legislature. UDOT has taken advantage of the latest in online technology to provide a live, data- and performance-driven report that is constantly updated to reflect how they are reaching their strategic goals. https://dashboard.udot.utah.gov/strategic-direction

TIP The content of your communication can be just as important as the person delivering the message. Consider how the audience will respond to the messengers selected to deliver the TAM communication.

Table 3.3 Comparing Formal and Informal Communication

Basis for Comparison	Formal Communication	Informal Communication
Meaning	Communication done through predefined channels set by the organization. TAM programs commonly use formal channels for cyclical reporting of performance, or engagement strategies to advance improvement projects.	The interchange of communication stretches in all directions and is uncontrolled. TAM programs commonly create change that manifests informal communication as people are experiencing the change. If managed carefully, it can help advance buy-in and increase the authenticity of program merits.
Otherwise known as	Official communication	Grapevine communication
Advantages	Timely and systematic flow of information. TAM communication strategies help agencies identify the message, timing and dissemination aspects of formal communication.	Efficient because the information can flow quickly and focus will be personal to the individuals. TAM program champions and advocates need to monitor informal communication and provide feedback to help refine messaging in official channels.
Disadvantages	More expensive and challenging to communicate personally to individuals and ensure understanding. More agencies have existing communication resources that can be leveraged. However, some consideration of targeted messaging to TAM stakeholders may require adjustments to existing channels.	Difficult to maintain secrecy and stop misinterpretation. Transparency and consistency in messaging about the TAM programs' expected benefits and expected implementation timings helps avoid these disadvantages. Should establish feedback mechanisms where there is anticipated risk of resistance to the TAM program.
Evidence	Generally written with recorded distribution. This can be useful as a historical timeline, as improvement is tracked over time. TAM implementations take time to make gains. Also good to have a record of past communication that reveals incremental improvement that is not apparent unless assessed over a longer time horizon.	Often no documented evidence of communication. Anonymity can be an advantage to receiving honest feedback about how the TAM program needs to adjust to advance improvement initiatives. Necessary to monitor informal channels to gain insights unavailable in formal channels.
TAM Example	TAMP, Data Reporting, Performance Reporting, Program Updates.	Peer-to-peer interactions discussion about progress, informal discussion driven by increased awareness and training.

Practice Example
Audience-Centric Communication

Region of Waterloo (Ontario, Canada) – Breathing Excitement into Asset Management

To assist in the implementation of a new Work Management and Decision Support System, the Region Water Services Division considered decision-making and needs across the organization, and communicated asset management system needs to the Division based around the people that would use the system. The Region created targeted communication tools that reinforced the vision of how asset management might impact people within their various roles in the organization.

By involving people in their current roles as examples, the tools reinforced how asset management frameworks are integrated within their existing work processes and what roles they play within the asset management process. They also highlighted the benefits of the change and how it would impact individuals personally across the organization. As the asset management system evolves through continuous improvement, so too does the need to find effective methods of communication and engagement.

TIP **Agencies can choose both formal and informal communication based on the situation Select the best approach for your agency based on your culture and context.**

Table 3.4 Overview of TAM Communication Mechanisms

Mechanism	Considerations (Pro: +, Con: -)	TAM Examples	
		Internal	External
Reports	+ Opportunity to provide detailed information the reader can digest in their own time + Formal communication that is a statement of a position at a defined time. - Can be hard to get feedback		TAMP Annual State of the Infrastructure Report
Websites Social media Push/ Interactive notifications	+ Highly interactive + Reaches many people quickly - Feedback is "public" and takes time to manage - Technology may not be accessible to all	Dashboard on internal metrics	Dashboard for performance reporting Consultation and feedback on service delivery
Brochures/ Post cards Newsletters	+ Enables simple messages to be clearly communicated + Internal newsletters can be used to inform and engage a broad audience - Can be expensive to produce (in physical form) - Not suitable for getting feedback	Quarterly updates on improvements/ achievements in TAM	Post cards on upcoming asset improvements
Presentations Training	+ Opportunity to interact and gather feedback + Opportunity for listeners to learn through experiencing - Requires significant time commitment from participants - Good for a few specific individuals, but challenging to influence more than a few	Formal training Focused status reporting to top management	Community meetings on upcoming asset improvements
Videos	+ Enables simple messages to be clearly communicated + Can quickly share information to broad audience + Opportunity for leadership to be involved in reinforcing a message - Can be hard to get feedback - Can be time consuming to develop		

Practice Example
Video and Media

Ohio DOT

Taking Care of What We Have: A message that defines the benefits that TAM brings through tangible examples that are linked to the DOT objectives. Ultimately this inspires confidence in the approach and the TAM decisions being made. https://youtube/A73b4dtE1Bk

Practice Example
TAMP Communication Plan

Georgia DOT

The Georgia DOT TAMP, published in 2014, included a communication plan to promote awareness of TAM and communicate the benefits of TAM practices. The communication plan highlights the goals and target audiences of communication and includes the key messages that are intended to be conveyed through various means. The main element of the communication plan is a table that lists the audience, communication strategies, and timeframe for the particular strategy. For example, in the near term the agency wants to have one-on-one meetings with members of the State Transportation Board regarding TAM priorities in their respective districts. Finally, the communication plan also contains brief measurement tools to gauge the reach and effectiveness of the communication efforts.

Practice Example

Importance of Communication for TAM programs

Vermont Agency of Transportation

Formal and informal communication can travel both upwards and downwards within an organization. Those responsible for TAM at VTrans proactively manage communication where it is practical to do so. When seeking to inform or influence senior leadership, VTrans' TAM program conveys not only the opportunities and impacts of funding decisions to decision-makers, but also provides context to foster informed choices. The TAM program builds support for the implementation, and elected officials and top management benefit from better context when TAM communication focuses on:

- **Understanding current and future performance and how it affects state strategic priorities:** How does asset performance influence agency objectives? For example, reducing the amount of bridges with an NBI rating of 1-3 needs to be related back to how freight movement, and economic indicators, can be improved.
- **The impact of decisions:** What will be achieved with additional/reduced funding or reduced restrictions on expenditure? With the use of life-cycle analysis and reporting of investment strategies, the TAM program can communicate the financial impact of different decision-making.
- **The benefit of TAM:** Report progress and how program successes are made relevant and advance agency objectives. These benefits are best articulated in terms that are understood by all throughout the organization, e.g. journey time savings/ reliability, and dollars saved. Communication about benefits also can confirm the benefit/implementation of previous decisions, and increase awareness of the success of "we did what we said we would".
- **Continual Improvement:** What VTrans' next TAM improvement will be and the benefit this will provide. Communication like this shows that the TAM program is heading in the right direction rather than continually being told to investigate/consider changes that may distract from strategic pursuits.

VTrans focuses on communication that reinforces confidence in TAM decision-making, to bolster stakeholder belief that the additional dollar invested will be spent in the right place at the right time. The agency also hired a communications consultant to help them develop engaging graphics to communicate critical and complex asset management principles into common, "every-day" storylines and language, transforming their AM approach and their TAMP into a product message that is easy to understand and digest.

How-to

Develop a Communications Plan

It is worthwhile to agree to and develop a communications plan so that everyone involved in TAM can help provide the most efficient and effective messaging. The four steps described in this How-To Guide provide an overview on crafting a communications plan that will use the right communication mechanism to reach the intended audience.

Developing a Communications Plan

1 Determine the scope of communications

2 Determine the types of communications

3 Determine the specific communications-related activities

4 Document the plan and assign roles and responsibilities

1. Determine the scope of communications

Who is the target with TAM-related communications? The typical audiences for communication include internal DOT staff, the legislature, and the public. It is also important to consider the goal for communicating to each of these audiences. This helps to shape and focus the communications activities developed later on. Here are some examples of the focus of communications for suggested audiences:

- For internal DOT staff, the goal of communication could be to convey the asset management processes in place within the agency in order to help staff understand how their work fits into the overall asset management functions.
- For the legislature, the goal of communication could be to describe the importance of asset management, the work being done with state and federal dollars to improve and promote asset management, and the need for continued funding to support TAM activities.
- For the public, the goal of communication could also include information on the importance of asset management. In addition, it could be worthwhile to convey the decision-making process in order to increase openness and transparency about how money is spent on projects throughout the state.

A communication plan could address different strategies for different audiences. A TAM communication plan could be the sum of plans for individual audiences. This approach would separate the communication products that would be developed for multiple audiences.

2. Determine the types of communications

It is useful to brainstorm and document all the different types of communication products available to utilize and implement. Types of communication include:

- Websites and webpages
- Workshops
- Public relations via local news outlets
- Public events
- PowerPoint presentations
- Brochures and reports

Combining the scope and the communication products will help to decide the level of detail and the visualizations needed to achieve the communication objectives.

TIP A well crafted communications plan will empower individuals or units within the agency to commu nicate. While this may require establishing some standards, limits, or constraints, the focus of the plan should be on providing tools and guidance to promote effective communication.

How-to

Develop a Communications Plan

3. Determine the specific communications-related activities

After developing a list of all the relevant communications opportunities available, it is possible to decide which specific activities to pursue in order to reach all the targeted audiences. This step is the substance of the communication plan. What type of communication should be used to provide information to each audience? What is the timeline for developing and delivering the communication materials? It is helpful to describe each activity in as much detail as possible so that the intent and implementation process are clear. Examples of communications related activities include:

- Offering a workshop for DOT staff and other stakeholders
- Developing a webpage dedicated to TAM
- Publicizing TAM activities via local news outlets
- Publishing reports and/or data on assets
- Attending legislature meetings

4. Document the plan and assign roles and responsibilities

The last step is to document the communication plan including the scope, types of communication available, and the description and timeline for specific communications activities. It is best to assign roles and responsibilities to each activity, so that the communication plan is implemented effectively.

Developing a Communications Plan

1 Determine the scope of communications

2 Determine the types of communications

3 Determine the specific communications-related activities

4 Document the plan and assign roles and responsibilities

Section 3.3

Managing Change

In general, TAM implementation or advancement involves introducing organizational business changes through the people, processes, tools and technology involved. The purpose of change management is to support the improvements that TAM introduces.

Managing change ensures that new initiatives introduced to reflect TAM principles are successful, effective, and sustained. Change management guidance can be applied to help advance organizational or process change, as well as systematic or technological implementations and their associated change.

This section has three parts:

1. **TAM Culture.** Changing an agency's culture can have widespread benefits to TAM programs. People's attitudes and behavior can be a powerful TAM ingredient.
2. **Understanding the Organization.** In order to advance TAM, a strong understanding of the agency's organization, potential challenges, and capabilities is necessary.
3. **TAM Change Readiness.** Change management typically begins with an assessment of the agency's readiness for TAM.

TAM Culture

Working toward widespread acceptance of TAM processes is a culture shift worth pursuing. DOTs are typically known for a "can do" attitude, and that can be powerful in creating the energy needed to make strategic change. An important aspect of culture change is to create open minds that are receptive to TAM advancement initiatives, so the whole agency can embrace them and lead them.

Changing an agency's culture can have widespread benefits to TAM programs. A culture that fully embraces TAM can make the best use of TAM tools and techniques to further advancement and progress toward maturity. When TAM culture is present and working well, the agency is able to achieve optimal results by working through conflicting perspectives on the key elements of the process.

TAM Change Agents

Making changes is inherent to TAM success. TAM teams need people who will guide and lead the change process. It is important to note that the person making decisions about what changes are needed is not necessarily the one who will carry out the changes. This requires a change agent with the ability to help people understand and adapt to new ways of doing things.

Practice Example
Change Management Success Factors

Colorado DOT

Colorado DOT's (CDOT) change management program seeks to "help all members of Team CDOT be successful with each and every change which impacts them." CDOT's people-centric approach to change management highlights the two-way flow of information system. Information can flow from project leads, to change agents, to supervisors, and finally to employees. However, information and ideas can also originate with the employees and flow back to the project leads. This encourages engagement from frontline workers. CDOT has identified the following contributors to success in change management:

- Active and visible sponsorship
- Frequent and open communication about the change
- Structured change management approach
- Dedicated change management resources and funding
- Employee engagement and participation
- Engagement with and support from middle management

Practice Example
Culture Change

Minnesota DOT

MnDOT has had a culture of innovation for a long time, and its TAM culture in particular has been advancing. The innovative nature of MnDOT has helped with TAM implementation, but the organization has struggled to fully embrace all of the elements of TAM. The need to institutionalize risk management is an important aspect of MnDOT's TAM program and progress is being made incrementally. TAM leadership understands that change takes time and they are making progress using a continuous improvement approach.

TIP Implementing TAM or improving TAM business processes involves changing the way the agency con ducts business. It involves people, processes, and/or technology. TAM improvement is a change process so it should involve change management techniques.

Understanding the Organization

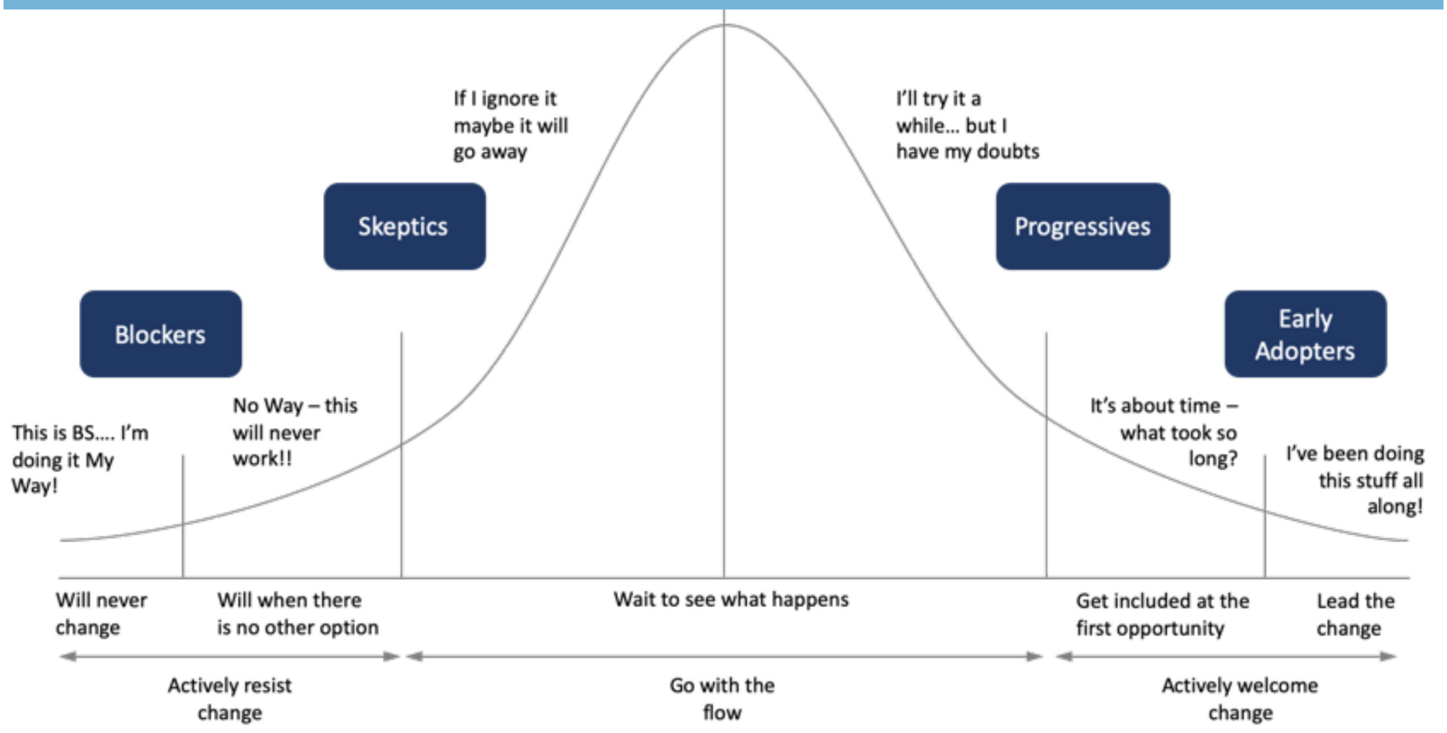
Transportation agencies must implement changes when adopting new asset management practices at the strategic, tactical and operational levels. TAM programs commonly focus on the changes required and less on how to successfully implement the change. Understanding the potential challenges and learning how to use the agency's support mechanisms are essential to advancing TAM improvements within the agency.

Building a TAM Organization

Agency leadership and TAM program management have extra roles to play as communicators, advocates, mentors and change agents. They may require extra tools to help them fulfill their roles, and even to cope with the TAM initiated changes.

People tend to have similar reactions to any change that will challenge the status quo. Those in favor of the TAM program changes, or those more adaptable to change, may more quickly move through the process of transitioning to new and improved ways of doing things. Figure 3.3 illustrates the range of receptivity to change and how to understand it so that it can be planned for.

Figure 3.3 An individual's response when presented with change



TIP Change is hard for some people to embrace. Apply proven change tactics to various audience types to bring all people in the organization along for the improvements.

Managers need to be equipped to advance more quickly so they can fulfill their support role successfully, even while they themselves are experiencing the effects of the changes the asset management program is implementing.

Asset Management Early Adopters

These are members of the organization who are already prepared to adopt asset management best practices, have been advocating for it in the past and are ready to see the change happen.

What They Need

- Communication channels that are targeted to manage expectations and minimize frustration
- Pilot projects that have good asset data, and can better model and inform tactical and strategic decision-making
- Opportunities to showcase early wins in the TAM transition

Asset Management Progressives

Asset management progressives are predisposed to see TAM as a change for the better. They see asset management as a good idea, are willing participants in the change, but need to understand the objectives and what the future will look like.

What They Need

- Communication channels that report on progress and highlight expected future improvements
- Training and reinforcement that emphasizes how they can help implement the change and how their own role may change

Asset Management Skeptics

Skeptics are predisposed to see TAM as a change for the worse. They are wary of proposed changes, and feel existing processes are effective and do not need to be "fixed." Messaging targeted to (or delivered by) Progressives will alienate this group and increase resistance.

What They Need

- Much more detail on how the TAM Program will be implemented and why the change is necessary
- Process mapping and other group activities that highlight where problems exist
- Once they are convinced that change is required, they will benefit from training

Asset Management Blockers

TAM Blockers are strongly attached to existing processes and will resist change. These individuals will take the longest amount of time to adjust. Some may never be able to make the change, and may choose to leave the agency if the change is implemented.

Tactics to Manage/Leverage

- Understanding of the root cause of their resistance, which may be related to a loss of control, status within the agency, or loyalty to past managers or staff
- Communication targeted to help them realize that TAM Program improvements within the agency are necessary.
- Activities or celebrations that recognize and acknowledge the foundational aspects of past good work over the agency's history

Practice Example

Application of Lean Six Sigma to Manage TAM Skeptics

New Brunswick Department of Transportation and Infrastructure (NB DTI)

Despite a long history and legacy of existing practices and a strong internal institutional resistance to change, NB DTI implemented Lean Six Sigma to better document existing practices and identify where improvements could be implemented for savings or service improvement. This helped advance and effect change. Over time, the program included increased efficiency, cost savings, refined procurement methods, and application of asset management decision-making to pavements, bridges, culverts, facilities and other transportation infrastructure. The use of methodologies like Lean Six Sigma can aid agencies with a focus on change management.

Practice Example
Process Change

Michigan DOT

When introducing a Maintenance Rating System, Michigan DOT (MDOT) started the change management process early in the project. Agency leadership was consistent and passionate throughout the project. The process was developed with involvement from individuals within each Region, including people in leadership as well as those on maintenance delivery teams. These discussions identified opportunities for consistency and enabled development of a system that represented actual performance and decision making.

The Maintenance Rating System was piloted within one Region that was most proactively seeking the information that the system provided. This enabled any kinks to be ironed out in the system and also developed individuals within MDOT who could train their peers in the system, results, analysis and opportunities for decision making. It also provided data that enabled the Regions to learn from the results, make a change in investment and improve the maintenance level of service delivered. The rating system was named the "Michigan Maintenance Rating System (MiMRS)."

During implementation MDOT identified a specific roles for coordinating and driving the system, and identified individuals within each Region that had shown interest in the system and competency in analytical assessment to be part of a user group to share knowledge and disseminate information. MDOT also shared the results and news stories internally to enable peer comparison and drive consistency. Leadership identified specific funding for projects developed based on the maintenance rating system results.

This process change was part of a broader MDOT approach to Performance Based Maintenance that included implementing a new inventory and maintenance management system. Performance Based Maintenance will enable MDOT to better understand their assets, the cost of maintenance and the cost to make improvements to asset functionality. The goal of Performance Based Maintenance at MDOT is to achieve a needs-based budgeting approach to non-winter maintenance and enable better decision by supervisors and management.

TAM Change Readiness

The TAM Program change management process should begin with an assessment of the agency's readiness for TAM. Thinking about how the agency has responded to change in the past, the general awareness of TAM across the agency and many other factors can help inform the process of preparing for and implementing change at the agency.

Change Readiness

Managers may need assistance to help them identify the cultural make-up of their groups, ways to help each individual advance with the asset management program, and tools to help reinforce successes as implementation progresses.

Difference approaches will be needed for different staff, and should be targeted to the right group. Assessing a target group's needs is important to ensure the right methods are employed. No one approach will be sufficient to overcome resistance with all groups.

Efforts that focus on knowledge, skills and abilities are required for all staff, but will initially be most effective with staff who are open to the change. Approaches that address wariness and resistance are also important to all groups, but may require greater effort for some. Others may also require training to understand why the change is needed.

The Assessing an Organization's Change Readiness Checklist provide a way to gauge your agency's situation in order to prepare for change.

System/Technology Change

System/technology changes can have a major impact on TAM operations and pro-cess¬es. Proactive management of these changes as they occur can go a long way toward yielding the positive benefits of system and technology changes.

Many state DOTs are currently embarking on total asset management systems. Intro¬ducing a major new system provides a good opportunity to undertake a comprehensive change management effort that addresses not only the required shifts in work process¬es and skills, but also the cultural changes that will ensure that the agency takes full advantage of the new technology to advance its practices. There is more information about the types of system and technology changes in Chapter 7.

The How-to Manage Change and Prepare for a System Replacement provides step-by-step guidance on being ready for a major TAM system replacement.

Practice Example
Change Management Due to System Change

Ohio DOT

In fiscal year 2016, ODOT began phasing in new requirements for the development of District Work Plans that combined Capital and Maintenance projects. At that time, Districts' Work Plans were required to match 25 percent of the lower cost treatments (such as chip seals and micro-surfacing) recommended by the pavement management system. For FY2017 and beyond, District Work Plans are required to match 75 percent of these PMS recommendations.

This change was met with concern by some district staff in regards to data quality in the PMS, and lack of familiarity with the new process. To address staff concerns, the Asset Management Leadership Team conducted workshops, bringing in staff involved in pavement programming from across the state. The workshop focused on actions that Ohio DOT could take to improve the PMS and its programming processes.

TIP Change Management Models such as Prosci s ADKAR® (Awareness, Desire, Knowledge, Ability, Reinforcement) can provide a framework that helps managers understand what tactics they need to employ for a given individual or group.

Practice Example
Change Management Due to System Change

Ohio DOT

In fiscal year 2016, ODOT began phasing in new requirements for the development of District Work Plans that coordinated all Capital and Maintenance activities regardless if these activities were sold projects or performed with internal maintenance crews. On initiation, District Work Plans were required to match 25 percent of the lower cost treatments (such as chip seals and micro-surfacing) recommended by the pavement management system to ease into the new process. For FY2017 and beyond, the District Work Plans are required to match 75 percent of these pavement management system recommendations over the planning horizon, six-years. This proposed change was met with concern by some district staff in regards to the lack of familiarity with the new process along with some misunderstandings of the data quality in the pavement management system. To address staff concerns, the Department conducted a workshop consisting of executive management, planning, pavements, design, and maintenance crews from each District and Central Office. The workshop brought in staff specialists from other states to discuss, eliminate any misconceptions, and answer any questions about pavement treatments and the pavement management system. The workshop focused on the synchronized and consorted efforts of all the Districts with the optimization of the pavement management system, will improve the overall Pavement Conditions throughout the state.

In 2019, ODOT expanded TAM collaboration by holding a TAM-TSMO workshop. The goal is to better align these strategic initiatives particularly due to each one's central focus on creating and utilizing data to realize greater operational efficiencies. These initiatives now hold combined executive direction meetings with the Governance Board to achieve strategic alignment.

In December of 2019, Executive Management approved the creation of a Chief Data Officer (CDO) position and subsequent Data Governance Office. This new office will combine with the existing TAM Audit Group section to provide a single source of Data Governance and Standards for both structured and unstructured data in the DOT.

Checklist

Assessing an Organization's Change Readiness

Assessing an agency's readiness is an important aspect of the change management process. Even before administering a particular readiness assessment, consider each question in this checklist to ensure the assessment and the change management process are effective moving forward.

- ☐ **How has the organization responded to change in the past?**
- ☐ **What are the organizational factors that will lead to successful implementation of TAM?**
- ☐ **Who are the people (or groups of people) in the organization with the most influence for TAM?**
- ☐ **Is the organization's structure amicable towards the change?**
- ☐ **What do employees know about TAM?**
- ☐ **Do employees support TAM or is there general resistance?**
- ☐ **What are the characteristics of TAM or specific TAM-related changes that the organization will respond best to?**
- ☐ **What is the best way to administer the readiness assessment?**
- ☐ **What scale will be used to assess the organization's readiness for the change?**
- ☐ **Is there an existing change readiness assessment model or tool that matches the organization's priorities?**
- ☐ **What else is going on that the agency that could impact the timing and successful implementation of these changes?**

How-to

Manage Change and Prepare for a System Replacement

System replacement or technology change can be one aspect of an agency's change management and TAM improvement plan. This How-To Guide presents four steps for preparing for system replacement, specifically incorporating change management techniques to enable a smooth transition. While the steps are specific to the scenario of replacing a key system, the principles from this How-To Guide can be applied more broadly to other scenarios of implementing change with an agency as well.

1. Assemble the team to lead the agency through the replacement process

System replacement is no small undertaking. It is vitally important to have a designated team of people to oversee the replacement process and ensure everything goes as smoothly as possible. When assembling the team, include people from each of the major areas of the agency that will be impacted by the new system. While some systems might be isolated to a specific group, many systems are integrated throughout the agency. It is important to have the perspective of people from across the agency to identify the problems and issues that might arise during the replacement process.

2. Test the system with a small team of staff

Before deploying the system agency-wide, test the system with a small group of staff members. This will help determine what issues might arise in the full deployment of the system. Identifying problems and potential hurdles early in the process will better prepare the team for the full implementation.

In addition, it is important to evaluate how the new system impacts work flow and integrates with other processes at the agency. It is rare that a new system will integrate seamlessly with all existing processes at the agency, so be sure to pay attention to the workflows that may change as a result of the system replacement.

3. Determine the training needs to enable a smooth transition

Using the lessons learned from the system test with the small group in Step 2, determine a training plan to ensure a smooth transition to the new system. It might be necessary to focus efforts on individuals in the agency who might have a harder time with a technology transition. People with less experience with the technology or who have been around the agency for a long time may be wary of the new system and struggle to adapt.

Preparing for a System Replacement

1. Assemble the team to lead the agency through the process
2. Test the system with a small team
3. Determine the training needs to enable a smooth transition
4. Determine the schedule for deployment

How-to

Manage Change and Prepare for a System Replacement

Consider the following training options:

- Workshops to introduce the new system.
- Documentation and guidebooks on the common features and use cases of the system that people can reference in their day-to-day work. Support documents (such as standard operating procedures and trouble-shooting guides) should be organized by business function to help employees effectively use the system in their daily work.
- A mentorship program that pairs people who are comfortable or familiar with the system with people who may need a bit more time to adjust.

4. Determine the schedule for deployment

Once the potential hurdles have been identified through a pilot test and a plan for training people on the new system is in place, determine the schedule for system implementation. Be sure to incorporate time for training. Also consider keeping the old system operational for a short period of time following the deployment, rather than shutting the old system down immediately following deployment. This ensures that functions can continue even if there are issues to be resolved with the new system.

Preparing for a System Replacement

1. Assemble the team to lead the agency through the process
2. Test the system with a small team
3. Determine the training needs to enable a smooth transition
4. Determine the schedule for deployment

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
Organizational Models	Emerging	• There is an increasing awareness of asset management among staff in some key departments within the organization and they are piloting or demonstrating though leading practice. There is an under-standing that service delivery and decision-making should follow a systematic approach. • There is an organizational structure that supports implementing and sustaining asset management practices consistently in each department of the organization.
	Strengthening	• There is a culture of asset management and an awareness among most staff that relationships exist between service delivery, infrastructure decision-making, and clear improvement actions to enhance the asset management system further. • There is an organizational structure that supports the continuous improvement of asset management practices consistently across the organization.
	Advanced	• The is a culture of asset management and an awareness among all staff within the organization that touches all aspects of service delivery and infrastructure decision-making at the strategic tactical and operational levels. • There is an organizational structure that supports implementing and sustaining asset management practices consistently across the organization. Embedded in the process are steps to continuously improve the organizational model and business processes.
Roles	Emerging	• Roles and responsibilities associated with the Asset Management Framework and have been defined, and the organization has begun the transition to the planned management system approach. • Senior leadership and some key staff involved in implementing asset management in the agency understand their role, and are accountable for ensuring asset management is embedded fully within the organization over time.
	Strengthening	• Roles and responsibilities associated with the Asset Management Framework and its processes are defined in most departments. • Key personnel in the organization including top management and other staff understand their role, and are accountable for ensuring asset management continuously improving across the organization.
	Advanced	• Roles and responsibilities associated with the asset management framework and its processes are clearly defined and are functioning effectively. • Everyone in the organization, from top management, to field staff, understand their role, and who is accountable for ensuring asset management is embedded fully within the organization.

Maturity Scale

Aspect of Practice	Level of Maturity	Typical Agency Status
Competencies	Emerging	• There is sporadic communication within the organization and externally to relevant stakeholders to help build support for the asset management framework and management systems. • Staff have growing awareness, knowledge, and capabilities to perform their role in alignment to the asset management system. • Attempts are made to implement change management strategies to improve and strengthen the asset management program.
	Strengthening	• There is regular communication within the organization and externally by the agency that helps build support for the asset management framework and management systems. • Key staff have an appropriate level of awareness, knowledge and capabilities to perform their role in implementing and improving the asset management system. • Change management tactics are developed in response to resistance to implementing actions that strengthen the asset management program.
	Advanced	• There is consistent, aligned and supportive communication within the organization and externally to relevant stakeholders that helps build support for the asset management framework and management systems • Staff have an appropriate level of awareness, knowledge and capabilities to perform their role in alignment to the asset management system. • A well crafted change management strategy helps implement improvement actions that strengthen the asset management program.

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Year: 2014
Link: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/529336/ODD_Module.pdf

Section 4.1
Introduction to Life Cycle Management

Section 4.2
Common Approaches to Managing Transportation Assets

Section 4.3
Managing Assets Over Their Life Cycles

Chapter 4
Asset Performance

Section 4.1

Introduction to Life Cycle Management introduces life cycle management and describes its importance to TAM, through examples of agency practice and how-to guides. It also stresses the importance of using performance objectives to drive life cycle decisions.

Section 4.2

Common Approaches to Managing Transportation Assets describes how the reliability-centered maintenance (RCM) process is applied to transportation infrastructure assets in order to select an effective life cycle management approach for any class of assets.

Section 4.3

Managing Assets Over Their Life Cycles describes how different life cycle approaches can be applied to managing assets. Guidance is provided for applying the common approaches described in section 4.2. the section provides information on the various technical aspects of each approach, and how life cycle management approaches can be implemented within agency organizations and business practices.

Chapter 4

Maximizing the Performance of Transportation Assets

Highway infrastructure represents a significant investment of public funds. With that investment comes the expectation that infrastructure assets will provide a safe and efficient means of travel to the public and the investment in these assets will be preserved. This chapter covers the strategies and techniques transportation agencies can employ to maximize the service life and performance of transportation assets and thus the service those assets provide to the traveling public. A focus is placed on life cycle planning which seeks to develop a structured approach to maximizing asset service life at the lowest practicable cost.

Key Terms

Asset Life Cycle.
The management stages of an asset including planning, construction, maintenance, rehabilitation, and reconstruction or replacement.

Asset Performance.
The ability of the asset to fulfill its intended function. While condition is sometimes used as a proxy for performance (e.g. pavements), for other roadway assets such as lighting, safety equipment and bridges, performance may not be adequately evaluated using condition alone. An asset's service requirement often helps select performance criteria for performance management, forecasting and measurement.

Capital work / investments.
Activities that create, expand, improve, renew, or extend the service life of transportation infrastructure. Common types capital investments include acquisition, new construction, enhancement, expansion, modernization, rehabilitation, and reconstruction.

Condition-Based Maintenance Management.
A maintenance approach in which maintenance activities are scheduled based on regularly-monitored performance. Typically, used on assets with long asset life cycles, and can sometimes lead to "asset preservation" interventions.

Interval-Based Maintenance Management.
A maintenance approach in which maintenance activities are scheduled at specific time intervals based on an analysis of asset performance. Used on assets with short or long life cycles and can sometimes lead to "asset preservation" interventions.

Life Cycle Planning (LCP).
A process to estimate the cost of managing an asset class, or asset sub-group over its life with consideration for minimizing cost, while preserving or improving the condition (23 CFR 515.5).

Life Cycle Strategy.
A standard, documented approach, resulting from LCP, that applies maintenance, preservation, and capital investment actions at each appropriate stage of the asset life cycle to maximize asset performance with available funding.

Maintenance.
Activities that are undertaken to prevent or address defects or usage effects that, if carried out, help ensure the asset achieves its expected service life. Examples of maintenance activities include, but are not limited to, pothole repair, crack sealing, painting, debris clearing, vegetation control, graffiti removal, and snow and ice control. For large complex assets, such as bridges or traffic signal installations, maintenance may include replacement of individual components. For small inexpensive assets, such as ground-mounted signs, pavement markings, all activities performed on an existing asset, including replacement, may be considered maintenance.

Maintenance Level of Service.
The desired performance established for an asset in terms of a measure that can be used to track the effectiveness of maintenance activities. Maintenance level of service is commonly established based on measurable conditions, or customer ratings where different measured attributes for different assets are related to a single scale. The common scale is typically A through E, or 1 to 5, but can be any consistent scale. Maintenance level of service can be used in planning and evaluating the appropriate level for various maintenance activities with available funds.

Operations.
Activities that allow service to be provided by the asset, however are not actions focused on the asset specifically. Snow plowing, sweeping, bridge operations, ITS communications, signal coordination, lane reversals and other activities that allow that asset to delivery mobility for users are examples.

Preservation.
Activities performed to achieve or extend the service lives of existing infrastructure assets, without changing the operational nature of the asset. Preservation may include both maintenance and capital investment activities.

Reactive Maintenance Management.
An approach in which maintenance activities are performed in response to reported asset failures or events, such as a vehicle collision or storm damage.

Reliability Centered Maintenance.
An approach for determining the maintenance requirement for any physical asset, based on its operating context within the agency. Typically, used on assets with shorter asset life cycles.

A Note on Terminology.
Maintenance, as defined at the start of this chapter, refers predominantly to Routine Maintenance, is not normally a capital investment, and does not increase expected asset service life. It is an intervention that may improve condition (e.g. filing a pothole) and ensures service life is realized.This definition is not universal, particularly given FHWA funding eligibility definitions. Maintenance in some jurisdictions sometimes refers to capital betterments, or service life altering interventions. Effort has been made to achieve consistency in the use of this terminology in this chapter. Instances where the term maintenance has a broader meaning are specifically indicated in the text.

Section 4.1

Introduction to Life Cycle Management

This section introduces life cycle planning and describes its importance for TAM through examples of agency practice and a how-to guide.

This section has three parts:

1. **Defining Life Cycle Management.** All transportation infrastructure assets have a life cycle, the stages asset travel from conception to removal or replacement. Life cycle management is the practice of considering the needs of infrastructure assets throughout their service lives, along with the cost and benefits of preventive and corrective actions that can be taken to optimize service life and to reduce the long-term cost of preserving asset condition.
2. **Establishing Asset Service and Performance Levels.** This section introduces the importance of establishing desired performance levels to drive the selection of the most appropriate life cycle scenario.
3. **Developing Life Cycle Strategies.** By establishing sound long-term strategies, agencies can extract the most value to the extent practicable with available revenue while minimizing future costs.

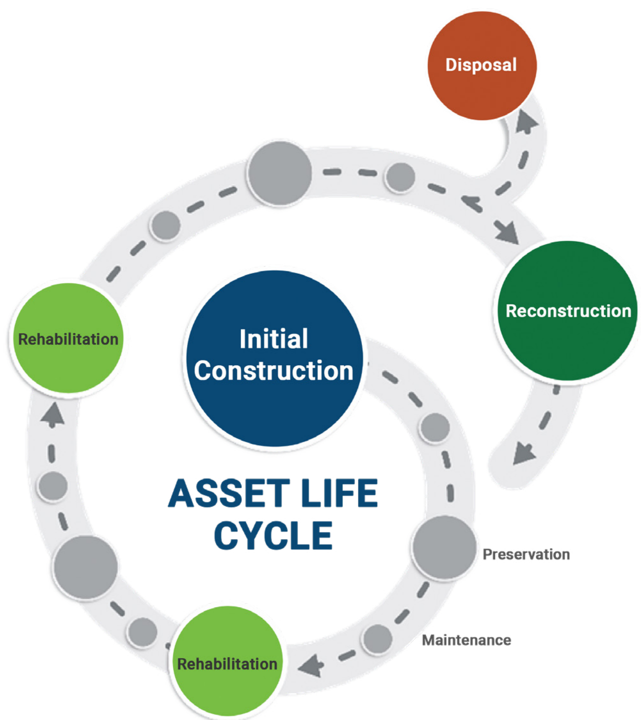
Defining Life Cycle Management

Through life cycle management, agencies employ data on asset condition, treatment options, costs, deterioration rates, replacement cycles, and other factors to determine the most cost-effective, long-term strategies for managing assets throughout their lives.

All transportation infrastructure assets have a life cycle, which includes several stages from initial construction to removal or replacement (see figure 4.1). Life cycle management is an investment approach that considers maintenance, renewal, replacement, or repair options through an asset's service life with the intent to maximize the benefit provided by the asset at the minimum practicable cost. It employs data on asset condition, treatment options, costs, deterioration rates, replacement cycles, and other factors to evaluate trade-offs between possible investment strategies and treatment timings. Effective life cycle management requires knowledge of the agency's strategic priorities and an understanding of the performance criteria driving investment decisions, so the right management strategy can be identified and implemented for each asset class. Aligning asset management measures with agency priorities ensures the investments made to extend asset service life provide the maximum impact to the agency's long-term goals.

Figure 4.1 illustrates a variety of interventions that occur over an asset life cycle. The larger circles represented in the figure are service life altering, and represent a capital investment in infrastructure. Capital investments provide significant life extension, and may alter or enhance the operational nature of the asset, e.g. expand capacity, without fully replacing the asset. Maintenance (reactive, interval based and routine) activities are required throughout the life cycle to ensure the asset achieves its service life. Preservation treatments restore condition or performance to achieve service life, and may extend service life as well, but do not significantly alter the operational nature of the asset. Some agencies may capitalize investment in these preservation activities; however, regardless of the timing and character of the selected interventions, all of them are part of the life cycle management process. More (lower cost) maintenance in-

Figure 4.1 Stages of an asset life cycle

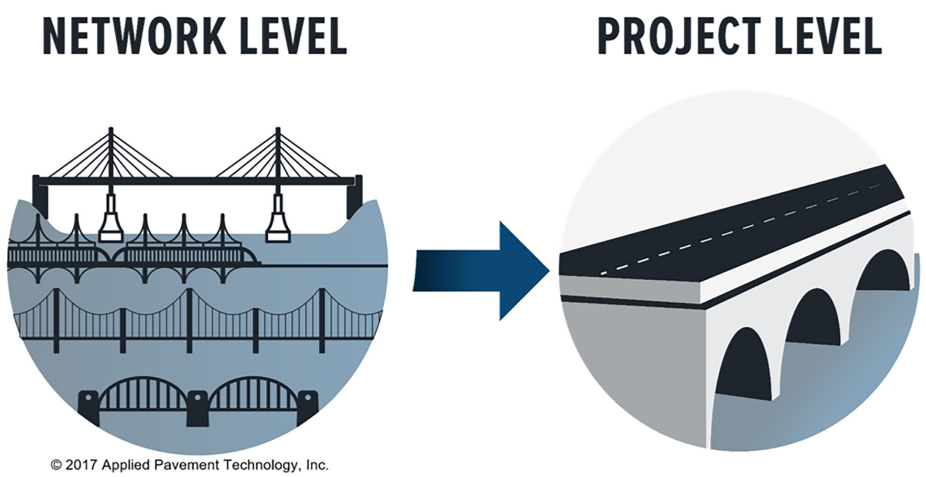


terventions can offset the number and cost of the larger (and more costly) interventions. Balancing the right intervention, at the right time, can greatly reduce the overall investment needed for infrastructure to be reliably available for providing service.

Life cycle management can be used at both network level and at project level. At network-level, life cycle management considers the needs of an entire asset class, as well as the available funding, to determine the most appropriate life-cycle strategies. For example, analysis can establish the optimal proportions of overall investment that should be allocated to different types of interventions over the network, to minimize investment to achieve performance targets or an average condition level. At a project level, life cycle management is commonly used to develop asset-specific strategies. Project level life cycle plans provide input into the network level life cycle plans. Large bridges or other distinct network components are often planned and managed in this manner.

Life Cycle Cost Analysis (LCCA) is an engineering-economics approach that can be used to quantify the differential costs of alternative design approaches. Network level life cycle management, while a more wholistic process that manages every stage of an asset's life, may employ LCCA or other forms of analysis to inform management decision-making. Figure 4.2 highlights some of the major differences between life cycle management and life cycle cost analysis. At the network level, LCCA can be used to understand how to best manage the network as it ages. At a project level, it is used to understand what are the most effective actions to be taken on the assets within the project scope at the time of project delivery. Both network level and project level analyses contain many aspects of engineering economic analysis, such as consideration of user benefits, user costs, and the time-value of money to identify alternatives that represent the lowest practicable life cycle cost over the analysis period to achieve the desired objectives.

Figure 4.2 Attributes of network level life cycle management and project level life cycle cost analysis



- High level.
- One asset class or subclass.
- Multiple locations.
- Looks at impacts of varied treatment timing.
- Considers future cost changes.

- Detailed.
- Multiple asset classes.
- Single location.
- Treatment timing fixed for all options.
- Uses discount rate.

Decision Making Context

Life cycle management is driven by the need for owners to provide consistent service to those that use the transportation system with the resources available. Infrastructure decision making can take place at several levels within an organization, and in each case, considers different but often interrelated factors. These are illustrated in table 4.1.

Figure 4.3 Analysis of KYTC Future Costs Under Two Strategies.

Source: Kentucky Transportation Cabinet Transportation Asset Management Plan. 2018.

Practice Examples
Pavement Life Cycle Management

Kentucky Transportation Cabinet (KYTC)

In the early 2000s, KYTC found that the cost of hot-mix asphalt (HMA) was increasing faster than its budget to maintain pavement conditions. In response, KYTC evaluated the feasibility of strategies that relied heavily on preventive maintenance overlays such as thin HMA overlays (< 1 inch), chip seals, cape seals, and slurry seals. KYTC found that while the costs of these treatments were substantially less than a traditional HMA overlay, their service lives were only marginally shorter. As a result, the agency began increasing the use of these treatments on its secondary system. As part of developing its risk-based TAMP in 2018, KYTC evaluated life cycle strategies, as shown in Figure 4.3 Analysis of KYTC Future Costs Under Two Strategies that expanded the use of preventive maintenance overlays to its parkway and interstate pavements. The analysis results led the agency to select a life cycle management strategy that maximizes the use of preventive maintenance overlays on secondary roads and parkways and increases their use on interstate pavements over time. As shown in Figure 4.3, this new life cycle strategy achieved conditions over the 10-year TAMP analysis period that would have cost an additional $644 million if they had continued to rely on traditional 1- to 2-inch HMA overlays. By implementing these improved strategies, KYTC has significantly reduced the risk that the infrastructure will reach an unsustainable cost to maintain in the future.

Table 4.1 TAM Decision-Making Contexts
Key Questions and Connections to Other Chapters

	Strategic	Tactical	Operational
Key Decisions	Setting goals and objectives.	Capital investment prioritization and scoping and Integration of maintenance and renewal strategies	Delivery of the capital program, routine maintenance, and highway-operations activities.
Decision Makers	• Senior Leadership • Commission / Board • Legislature • External Partners	Directors and managers who are asset stewards.	District and field mangers, supervisors, and staff.
Key Questions	• What should our transportation system look like in the future? • How do we cater to the mobility needs of the future? • What should our focus and priority on infrastructure investment be? • With whom does decision making authority lie?	• How much money do we require to maintain our network? • Where and how should we allocate investment to maximize value for money? • What level of performance is acceptable for users for our transportation system, and what condition should we be targeting to support those service levels? • What criteria should be used to determine benefits for cross asset or cross program optimization?	• How should we deploy our resources (e.g. budget, staff, equipment, data) to ensure assets perform as expected and deliver reliable service? • Do we have effective programming, contract-development, and work management processes to deliver needed work on time with available resources? • How do we measure the impact of maintenance interventions on asset performance?
Other Factors	Decisions and outcomes of these strategic questions help focus investment. They add value to overall performance of the transportation system by setting priorities, values, and help prioritization of investment at lower levels. Creating new assets and disposing of existing ones are strongly influenced by decisions and priorities defined at this level. **Chapter 2** discusses these considerations in more detail, and the level of service section in this chapter discusses linking these strategic priorities to decision-making at lower levels. Performance and target setting in **Chapter 6** also discusses this linkage and how targets can be set to achieve these strategic goals.	This Chapter focuses on these questions and on the analysis that informs their corresponding answers and decisions. Life cycle management and analysis focuses on the existing transportation system and evaluates how: • How the asset is expected to deteriorate over time. • How the asset may fail prematurely. • How demands on the system are anticipated to change in the future. • What kind of interventions, investments could be selected. Asset Enhancement / Asset Acquisition / Creation of new infrastructure is also informed by LCCA, particularly through ensuring the entire life cycle cost associated with a new asset is considered during its planning. This sometimes requires a change in corporate culture and is discussed in **Chapter 3. Chapter 5** discusses how resource allocation is accomplished to balance investment needs to achieve.	Delivering a program work, ranging from maintenance activities to capital improvements, requires a coordinated management of a large workforce. It requires processes that minimize input of resources to get the output required for desired system performance. Work management systems, efficiency and improvement techniques and performance management focus on improving decisions at this level. These concepts are discussed in **Chapter 5, 6 and 7.**

Defining Asset Service and Performance Levels

Before asset performance can be managed, an agency must first define what it is seeking to achieve. In TAM, asset performance is most commonly defined in terms of asset condition or maintenance level of service. Performance may also be evaluated in terms of safety, availability, reliability, resiliency and other service attributes. Regardless of the method used to monitor performance, it should be used to inform analysis that supports decisions to help ensure that investments enable an agency to achieve its goals cost-effectively.

Establishing Desired Levels of Service

Before a whole-life strategy can be developed and implemented, an agency must determine what they seek to achieve. In many transportation agencies, the desired level of service (or asset management organizational objectives, in ISO 55000 terminology) provides the linkage between what the goals of an agency are, and what investments and interventions should take priority when managing assets. High level goals should directly influence investment choices when resource allocation decisions are made. Service levels help establish when gaps need closing to achieve a goal, and merits investment. Chapter 2 discusses ways to create linkages between goals and investment decision making.

When managing the life cycle of existing assets, performance targets are commonly established as a way to manage service levels for the transportation network. How to determine the expected level of performance may vary depending on the type of asset being managed. Level of service targets that are part of performance framework typically are a mixture of both customer focused performance measures, and technical service measures that help those responsible for the asset assess what types of interventions might be required and when. Customer focused service measures are important to road users and other stakeholders that require mobility. Travel time reliability, safety, load capacity and clearances, and lane availability are all examples of service targets that are customer focused. Condition, strength, regulatory compliance and examples of technical service attributes are commonly of greater interest to asset stewards than asset users. Both types are service level targets that are important to evaluate the efficacy, effectiveness and efficiency of a transportation system.

For pavements and bridges, and other assets managed using a condition-based approach, asset condition is commonly used to establish expected technical levels of performance, but also is relevant to customers. For example, condition is employed as a proxy in this way for pavements because it is objectively measurable, deterioration has some predictability. It is a valuable service attribute because often, user experience is also directly connected to condition as well. Potholes, rutting and roughness all reduce quality of service from a pavement. Performance measures, such as those discussed

TIP The organizational objectives provide the overarching context and direction to the organization s activities, including its asset management activities. The organizational objectives are generally produced from the organization s strategic level planning activities and are documented in an organizational plan. (ISO 55000, 2.5.3.4) These organizational objectives are analogous to strategic objectives typically found in long range transportation plans.

in Chapter 6, are used to establish the desired long-term performance and to set short-term targets that can be used to track progress towards the long-term objectives. For other highway assets, including those managed using interval- or time-based maintenance approaches, performance may be linked to the expected service life, the ability of the asset to fulfill its intended function, and/or other operational factors. For these other highway assets, performance targets are often established as part of a Maintenance Quality Assurance (MQA) program in terms of desired maintenance levels of service (MLOS) and integrated with operational service targets that may also be customer focused.

Risk can also be used as a measure of performance. As described in chapter 2, risk considers both the potential impact and consequence of failure. This can be particularly useful when the potential consequences of failure impact other assets or facilities.

An example of how Colorado uses risk to manage rockfalls is included in section 4.3 of this chapter. Additional details on how to track risk-based performance measures is included in Chapter 6.

Establishing a desired level of performance is typically a collaborative process that considers existing conditions, available funding, expected demands on the system, policy goals and guidance, and stakeholder priorities. The desired level of performance is typically established once baseline data is available, so performance trends can be evaluated. The desired level of performance may be adjusted over time to reflect changes in agency performance, changes in asset condition, capacity, safety, resiliency and other factors.

Practice Example
Maintenance Levels of Service

Colorado DOT

Each year, CDOT must report on departmental performance to its legislature, and a frequent topic is the condition and maintenance of highway infrastructure. The agency supports the annual maintenance portion of this report with its Maintenance Level of Service Measure, which rates the delivery of services in nine program areas in terms of a letter grade from A to D and F. The agency has used historic data to develop forecasted performance curves for each service area that estimate the resources needed to improve the maintenance level of service by a given amount over a specific time period. These estimates are summarized in a presentation to the legislature to report on current performance and expected performance given anticipated funding for each program area. The figure provides an example of information on MLOS in the 2016 Report. Once the targeted MLOS is established, maintenance funding can be allocated to ensure that agency priorities are met.

Maintenance Levels of Service by Program Area

Maintenance Program Area Description	Funding Needed for 'A' Rating	Budget FY2016-17 Funding	FY 2013-14 Budget	FY 2014-15 Actual	FY 2016-17 Projected
Planning, Training and Scheduling	$25.4M	$15.9M	C-	C	C-
Roadway Surfacing	$177.2M	$40.0M	B+	B+	C+
Roadside Facilities	$41.7M	$22.3M	A-	B+	C
Roadside Appearance	$12.7M	$8.6M	B	B-	C
Traffic Services	$109.5M	$67.7M	C+	C+	C-
Bridges & Structures	$122.0M	$12.2M	B-	C+	C
Snow & Ice	$88.5M	$73.5M	B	B	B
Service Equipment, Buildings & Grounds	$25.1M	$15.7M	C+	B-	C-
Tunnels	$9.8M	$6.2M	C+	B-	C+
US 36 (mtc. contract)		$1.2 M			
OVERALL MLOS	$611.9M	$262.6M	B-	B-	C+

Colorado DOT Example of Funding Needed to Support Maintenance Levels of Service.
Source: Colorado DOT. 2016. https://leg.colorado.gov/sites/default/files/cdot_smart_2017_presentation.1.pdf

Three types of service expectations are often used in combination to manage asset performance:

- **Performance target –** the level of performance beyond which additional performance gains are not desired or worth the additional cost. When performance is measured based on condition, the desired performance may describe the desired state of good repair. There may be an expected specific time frame to achieve this desires performance target.
- **Current Performance –** an intermediate level of performance achieved by the organization and is usually reported relative to the desired target. Target setting is described in more detail in Chapter 5.
- **Minimum acceptable performance –** the lowest level of performance allowed for the asset or asset class to still function as designed.

Performance expectations may be set for the road network, a road corridor, for individual assets or for a group of assets.

Commonly, performance expectations are set using a combination of asset class or subclass or sub network, such as:

- Key network corridors.
- Bridges on the National Highway System.
- Interstate pavements.
- Culverts larger than 10 feet in diameter.
- Traffic signals serving more than 10,000 vehicles per day.

The nature of performance expectations can be either strategic or tactical or operational. Strategic expectations support freight movement; for example, the long-term goal of providing unrestricted flow of legal loads is supported by a performance expectation of no load-posted or restricted bridges on interstate highways. This expectation cannot be accomplished without the tactical delivery of work to address factors contributing to the physical condition of bridges. Thus, an agency may include tactical expectations to perform maintenance and repair on structural members on a routine basis or as conditions warrant. These enhancements

Practice Example
Maintenance Levels of Service

Washington State DOT

When seeking to establish the connection between investments and performance across a wide range of assets or roadway attributes such as litter, vegetation height, drainage, or functionality it is helpful to relate all of the various measures of performance to a common rating scale. Washington State DOT has developed its Maintenance Accountability Process to establish the relationship between maintenance level of effort and the resulting level of service. The process rates conditions and services in seven areas using a common letter-grade system, or MLOS.

- Roadway Maintenance & Operations.
- Drainage Maintenance & Slope Repair.
- Roadside and Vegetation Management.
- Bridge & Urban Tunnel Maintenance and Operations.
- Snow & Ice Control Operations.
- Traffic Control Maintenance & Operations.
- Rest Area Operations.

Each group of services or conditions includes several performance measures, which are translated to the MLOS grades of “A” (highest performance), “B”, “C” (adequate performance), “D” or “F” (unacceptable performance). Applying the MLOS grades allows for a consistent means of rating performance across services and geographic regions. Letter grades can also be represented in photographs of facilities that meet the criteria for each condition state to support communications with stakeholder groups. The MLOS are outcome-based measures that allow the agency to predict the expected level of service that can be achieved based on anticipated budget and work planning decisions. By tracking maintenance expenditures and MLOS results annually, Washington State DOT is able to adjust its maintenance priorities and budgets to address system needs and stakeholder wants.

Source: https://www.wsdot.wa.gov/Maintenance/Accountability/

TIP A desired state of good repair is often established as the level of performance beyond which further performance gains are not necessary or desirable, usually represented as a condition state for a set of assets.

can be also integrated with renewal and other rehabilitation interventions to help improve both tactical performance metrics, as well as achieve higher level goals and objectives. Operational improvements such as more responsive snow clearance, and better signage are all integrated treatment options to achieve the strategic objective.

Life cycle management analysis, and the decisions it supports, require service levels, performance targets and other objectives to be able to determine the optimal choices for agencies to select during resource allocation. Over an asset life cycle, a range of interventions are possible, from reactive, routine and preventative maintenance, to large investment associated with renewal, replacement, or removal. Having targets helps select the right interventions and investment option while balancing risk, service and cost.

Connecting performance measures to higher level strategic goals also supports an agency's ability to communicate how technical measures relate to system performance as experienced by highway users and other external stakeholders, thus tying asset management outcomes to system performance. Asset management measures are often very technical. Performance indicators like bridge ratings, pavement distress measurements, and risk ratings are not commonly understood by those outside transportation agencies. However, agencies can use these technical measures to support the performance indicators that are more commonly understood and prioritized by system users and external stakeholders. Communicating system performance and the status of the road network is discussed in Chapter 2, and is illustrated in several examples below. Customer service level targets are often established for this purpose, and give users an ability to understand the quality of service they should expect on the transportation system.

Practice Example
Establishing Desired Maintenance Levels of Service

New Zealand

New Zealand's Local Government Act of 2002 requires councils to consult with their communities on their 10-year long-term plans (which includes a 30-year infrastructure strategy). To do this, councils must prepare a consultation document. The consultation document provides an effective basis for public participation in infrastructure decision-making associated with the long-term plan. It includes a fair representation of overall objectives, and how tax levels, debt, and levels of service might be affected by the intended plan and can be readily understood by interested or affected people. The Auditor General recently reviewed consultation documents produced by councils. Key findings highlighted aspects that help define good practice:

- Consultation documents present information in a concise, readable and understandable way.
- Clear and unambiguous explanations on why proposed taxation and debt increases and significant changes in plans or intentions were considered "affordable" or "equitable" make consultation documents more effective.
- Consultaton document present technical subjects in a relatable way, without over-simplifying the issues. For example, one council used a road-trip analogy to help make technical subjects easy to understand.
- Using a personalized approach helps connect with the readers. For example, one consultation document used two primary school children, Maia and Xander, who are pitched as the "champions of the Long Term Plan 2018-2038."

By focusing on the inclusion of transportation customers, New Zealand municipalities are better able to address customer needs, inform customers of the actions they are taking, and refine work planning practices to address concerns critical to infrastructure operations and customer expectations.

"We've been doing lots of tuning under the hood to keep costs low" (page 2)

"Stop! We're at a crossroads, a fork in the road; a decision needs to be made about how we proceed on our road trip into the future" (page 6)

"Our rates are similar to your car rego, where some of it is set, and some is variable depending on the type of car you have" (page 24)

How-to

Establish Customer-Based Service Level Targets

In many industries, service level agreements (SLA) are a common way for businesses and customers to understand the services being provided, the measures or key performance indicators (KPI) by which the service will be measured, and the level of performance that is expected for the price being paid. Homeowners may have SLAs for multiple services such as plumbing and heating, lawn care, or snow removal. In the public sector there is no formal SLA between the public agency that manages infrastructure and the individuals and groups who receive services from that infrastructure. However, many agencies find that establishing KPIs based on customer-needs and expectations is an effective way of informing budgetary, work planning, and capital programming processes to ensure that the agency's investments adequately serve system users. This How-to provides an overview of a process agencies can follow to establish KPIs and related performance targets based on customer, or stakeholder, input.

1. Define Stakeholders

The first step in establishing customer-based targets is to identify the customers. While customers are generally considered to be system users, there are many more individuals and groups concerned with transportation infrastructure than just those who use the transportation system. Figure 4.3 provides a list of typical stakeholders, but there are many more stakeholders than those listed.

2. Articulate what each stakeholder wants out of your transportation system

Each stakeholder has a unique set of wants with the transportation system. Most stakeholders have multiple requirements; however, the purpose of this step is not to assign all service requirements to the right stakeholder, it is only to be sure to capture all potentially relevant service requirements. This can be done through many different approaches such as: customer or industry surveys, direct meetings, or customer-feedback web or social media outreach. This effort should be as extensive as practical and updated frequently. While passive gathering of information is inexpensive, it may lead to over representation of some stakeholder groups and under representation of others. The agency's environmental justice policy or procedures can serve as a resource for engaging with groups that may otherwise be underrepresented.

Recruiting for TAM Roles

1. Define Stakeholders
2. Articulate what each stakeholder wants
3. How would you Measure their want
4. Which of those measures are most important
5. Establish service level statements and KPIs

How-to
Establish Customer-Based Service Level Targets

3. Determine how to measure or demonstrate that you are fulfilling the wants or desired services

Once the services desired by each stakeholder have been defined, the next step is to establish a means of measuring the delivery of those services. At times it may be possible to directly measure the service, but often that is not the case. Agencies sometimes use a standard to ensure a service requirement is met. Compliance with a standard becomes the performance measure. Other service attributes require measures that can be identified as a service target. These may change over time, given service level expectations and willingness to pay. Additional guidance on establishing performance measures can be found in NCHRP Report 551, *Performance Measures and Targets for Transportation Asset Management* and NCHRP Report 422, *Maintenance Quality Assurance Field Implementation Manual*.

4. Which of those potential measures are most important for investment decisions?

Determining which measures should be selected as KPIs is not a simple process and should be revisited regularly. It is best to focus on a few KPIs that are directly related to stakeholder needs or perception of performance than try to manage using a long list of measures. The more directly KPIs relate to the agency's business decision and stakeholders' understanding of performance, the better. For these reasons KPIs based on user experience such as congestion, safety, or freight movement can be advantageous. However, these may not relate directly to asset management metrics, which tend to be focussed on asset conditions.

There is also a need to choose KPIs which can be measured accurately and at the lowest expense. Using a prioritization matrix to rank potential KPIs based on their effectiveness in communicating stakeholder wants and ease or expense of reporting can be a good means of selecting the set of KPIs that will best serve the agency. Chapter 6 provides additional information on selecting performance measures and targets.

It is important to note that none of the criteria used to select are static. These criteria will change with time, so agencies should revisit their list of KPIs on a regular basis to make sure they are still the right measures, and there isn't a more cost-effective means of collecting the needed information. The process of updating KPIs should be documented in an agency procedure or policy.

5. Establish service level statements and KPIs for reporting to stakeholders

Service level statements can be derived from the resulting KPIS to address specific stakeholder wants. Using the example materials shown in figure 4.3, a resulting agency service level agreement might be:

The agency will provide a transportation network that:

- Is in good condition: (How Good? See Condition Target)
- Has sufficient capacity (How sufficient? See Travel Time Targets on commuter corridors)
- That is available to users 24/7 (How available? See Lane Closures measures)
- Is managed through responsible investment (How responsible? See our AMP and BCRs for all investments); while leveraging cost-staring opportunities with our partner stakeholders (See Cost Sharing Targets)

Recruiting for TAM Roles

1. Determine the roles needed in the TAM program
2. Determine the competencies needed
3. Determine internal or external candidate
4. Develop a steering committee charter
5. Advertise and fill

Figure 4.4. Example in support of establishing key priority indicators

Define Stakeholders	Stakeholder Primary Requirement	Potential Measures/Standards to meet stakeholder service requiremetns		Potential KPIs that influence capital investmenttt decisions	
		Standard	Measure	Potential Service Level Reporting	KPIs, Priority given to projects that enhance
Users					
Residents	Condition		Condition	State of Infrastructure	Condition
Commuters	Reliable travel time		Travel time / Flow rate data	Commute travel times	Travel time
Tourists	Clear signage for wayfinding	Sign Design Standards	% of network compliance	Annual Reporting/Trends	
School Buses	Wide shoulders/good sight distance	Road Design Standards	% of network compliance	Annual Reporting/Trends	
Service Provider Network Users					
Transit Providers	Reliable Travel Time for scheduling		Travel time / Flow rate data	Schedule On-Time rates	
Couriers and Freight Carriers	Bridge capacity and defined truck routes	Truck Routes	% bridge restrictions on truck routes	Annual Reporting/Trends	
Taxis	Available network 24/7		Lane closures rates	Annual Reporting/Trends	Availability
Regulatory Agencies					
FHWA	Compliance to standards		% of network compliance	Annual Reporting/Trends	Compliance
AASHTO	Compliance to standards		% of network compliance	Annual Reporting/Trends	
EPA	Compliance to standards		% of network compliance	Annual Reporting/Trends	
Wider Community					
Active Transportation Advocates	Bike lanes / paths	Bike route corridors	% designated network with bike lanes	Annual Reporting / Trends	
Agency Staff	Clear Objectives		Clear service levels / targets	AM Policy / AM Objectives	
Taxpayers	Getting value from investment	AMP, Decision Framework	Portfolio valuation, Benefit Cost Ratio	AM Plans / Valuation	Investment BCR
Neighbors					
Neighboring States	Good interconnectivity		% boundaries with constraints	Annual Reporting/Trends	
Metropolitan Planning Authorities	Cost sharing opportunities		% collaboration on potential projects	Annual Reporting/Trends	Cost shared

Developing Life Cycle Strategies

Most transportation infrastructure assets have long service lives, lasting years or decades. Making decisions based on short-term performance without an understanding of the long-term cost effectiveness usually leads to higher future costs. Through life cycle management, agencies can develop strategies for maximizing their ability to meet both short- and long-term goals with available resources.

Adopting life cycle management can often achieve desired performance levels at lower life cycle costs than traditional strategies. Improved performance comes from analyzing the impact of various sequences of treatments on the future performance and costs of an asset class or subclass. By comparing the costs and benefits of long-term sequences of treatments, agencies can develop life-cycle strategies which provide the best practical long-term performance at lowest practical long-term costs. The implementation of life cycle strategies also enables an agency to better address its stewardship responsibilities and improve the alignment between agency investments and priorities.

By establishing sound long-term strategies, agencies can minimize the life cycle costs of preserving assets, while also managing asset performance to a defined target, the extent practicable with available resources. While strategies with a short-term outlook may provide better short-term performance, they can greatly increase the risk of higher future costs.

Life cycle strategies in construction and design stages

Transportation infrastructure assets are expected to provide agencies with a desired level of performance over their design lives. To ensure the desired performance is achieved, decision-makers should consider factors that

Practice Example
Managing Long-Life Assets

When developing long-term strategies, it is important to differentiate between the primary asset, with a long service life, and elements or components of that asset, that may be repaired or replaced to allow the primary asset to achieve its design life. In the case of pavements, the pavement structure may require several wearing surface replacements, either through overlay or removal and replacement of the wearing surface, to ensure the pavement structure lasts as long as intended. For assets such as bridges or signal installations structural elements or functional components may be repaired or replaced multiple times within the service life of the primary asset. In almost every case failure to perform these maintenance and preservation actions, or failure to perform them at the appropriate time will lead to reduced service life of the primary asset.

When determining the appropriate treatment for a long-life asset, it is important to understand the root cause of the condition being prevented or corrected. Inexpensive treatments that address the visible or measured condition without addressing the cause of the distress are not cost effective. Examples of such treatments include:

- Thin overlays of asphalt pavements that are displaying structural cracking.
- Painting corroded structural steel members without proper surface preparation.
- Filling leaking bridge joints without proper materials or preparation.

While such treatments may, in some specific circumstances, be needed to provide minimal function or safety until a more substantial repair can be made, they should not be considered part of an optimal life cycle strategy.

Treatments made to achieve or extend the service life of these assets can also address changes in conditions or assumptions that have occurred since the asset was designed and constructed. Examples of these types of treatments include seismic retrofitting or applying scour protection to bridges, or increasing the hydraulic capacity of corrugated culverts by relining with smooth interiors. Each of these treatments reduces the risk of premature failure to an extreme event, and may at the same time address other structural or functional needs, without replacing the primary asset or changing its functional nature, i.e. increasing traffic-carrying capacity.

impact asset service life and future costs at the time of construction. This is commonly performed as part of the project development process to select a preferred design alternative. Factors to forecast should include design criteria, constraints, standards, and risks.

- Traffic
- Environmental and climatic conditions
- Material properties
- Design standards
- Operational constraints
- Construction practices
- Climate change
- Changing customer expectations
- Regional, state and national travel pattern changes
- Advancing technology

Because these factors contribute to asset performance, deterioration and the continued functionality of the asset, they must be considered when developing life cycle strategies in early and later stages of asset life. Life cycle strategies are based on an understanding of how these factors contribute to the rates of deterioration, how well the asset will accommodate future requirements and which treatments are effective in addressing deterioration or slowing the rate at which the asset deteriorates or underperforms.

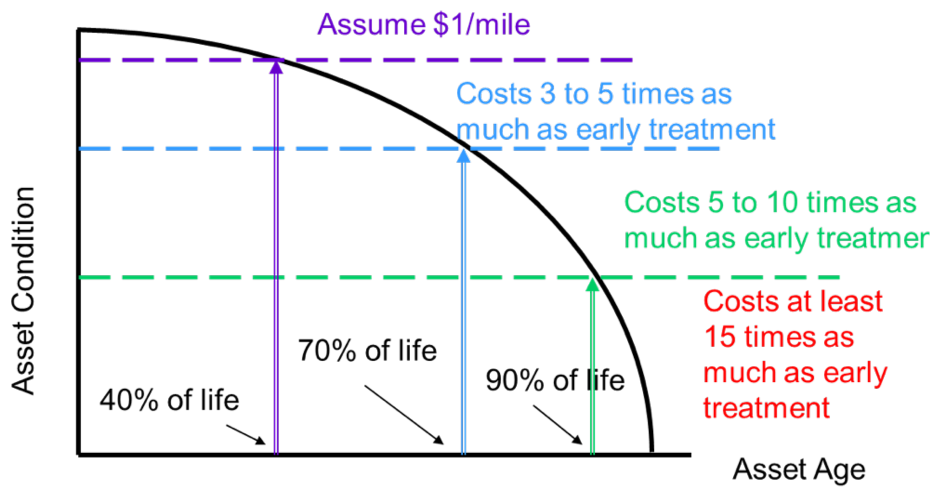
Operation, maintenance, and rehabilitation strategies

Treatment strategies consider how the asset, once constructed, will be managed to ensure it attains its design life, while maintaining the desired level of functionality. Special consideration should be given to long-life assets. There are three primary reasons short-term strategies are inefficient for long-life assets:

- As long-life assets age, deterioration accelerates, and there is greater risk of performance failing to meet current needs.
- As deterioration increases, the cost of treatments addressing deterioration tend to increase exponentially.
- Inexpensive treatments that restore condition but do not address the root cause of the deterioration will fail prematurely, leading to higher future costs.

These factors are reflected in Figure 4.5, which illustrates these concepts using a generic asset deterioration model. As shown in the figure, the average cost of treatment increases substantially as assets age. Additionally, the rate of deterioration tends to accelerate as assets age. Long-term strategies that use low-cost treatments early in an asset's life cycle tend to improve asset condition very cost-effectively by deferring the need for most costly repairs.

Figure 4.5 Example Showing the Cost of Deferred Treatments



Practice Example
Use of Incremental Benefit Cost to Demonstrate Long-Term Benefits

South Dakota DOT

To analyze the benefits of potential actions at the network level, South Dakota DOT (SDDOT) uses incremental benefit cost (IBC) analysis and deterioration models to determine the combination of feasible reconstruction, rehabilitation, and preventative maintenance treatments and timing at the network level that will give the best overall pavement and bridge conditions at the lowest practicable life cycle cost.

IBC analysis is used to answer a series of two important questions regarding pavement section treatments: Should the section be improved now, and if so, what is the best improvement to make? SDDOT's IBC analysis process answers this set of questions by determining the combination of feasible reconstruction, rehabilitation and preventative maintenance treatments and timings that will use the anticipated state funds to yield the optimal overall asset conditions on the state highway network over a 20-year analysis period and the best long-term value to the system users (SDDOT TAMP, 2018).

Considering Transformational Changes in Life Cycle Management

Life cycle management requires an understanding of past performance to predict future performance and plan appropriate actions. However, as technology advances and society's needs change, the inputs and objectives of life cycle management need to adapt. Technology can lead to new materials or techniques that allow agencies to get longer life from existing assets. However, technology can also lead to broader societal changes that may make the need for some assets obsolete. Similarly changes in standards and regulations, may make it necessary to replace or update some assets prior to the planned ends of their service lives. Asset managers should regularly review their assumptions about anticipated asset service lives, consider new treatment options, and adjust to technological and regulatory trends and adjust the life cycle approach accordingly. Much of the information to support this effort can be found in agency's long-term planning documents, as discussed in Chapter 2.

Incorporating Resilience in Life Cycle Strategies

Environmental changes such as extreme weather, temperature rise, sea level change, and changes in other environmental conditions can threaten transportation infrastructure. Even when these changes don't increase the risk of failure, they can require infrastructure owners to change their strategies for managing assets. This is particularly important for long-life infrastructure assets such as bridges, pavement, culverts, and geotechnical assets.

Resilience is the term used to describe an asset's ability to withstand environmental changes. Resilience can be considered at all stages of an asset's life and should be an integral aspect of any life-cycle strategy.

FHWA developed the Adaptation Decision-Making Assessment Process (ADAP) as a tool for planners and designers to address resilience in the design of infrastructure projects. While ADAP was developed to be used on a project-by-project basis, it can also be applied to the development of a lifecycle strategy. Figure 4.6 shows the 11 step ADAP

Practice Example
Using Root Cause Analysis and Improving Asset Performance

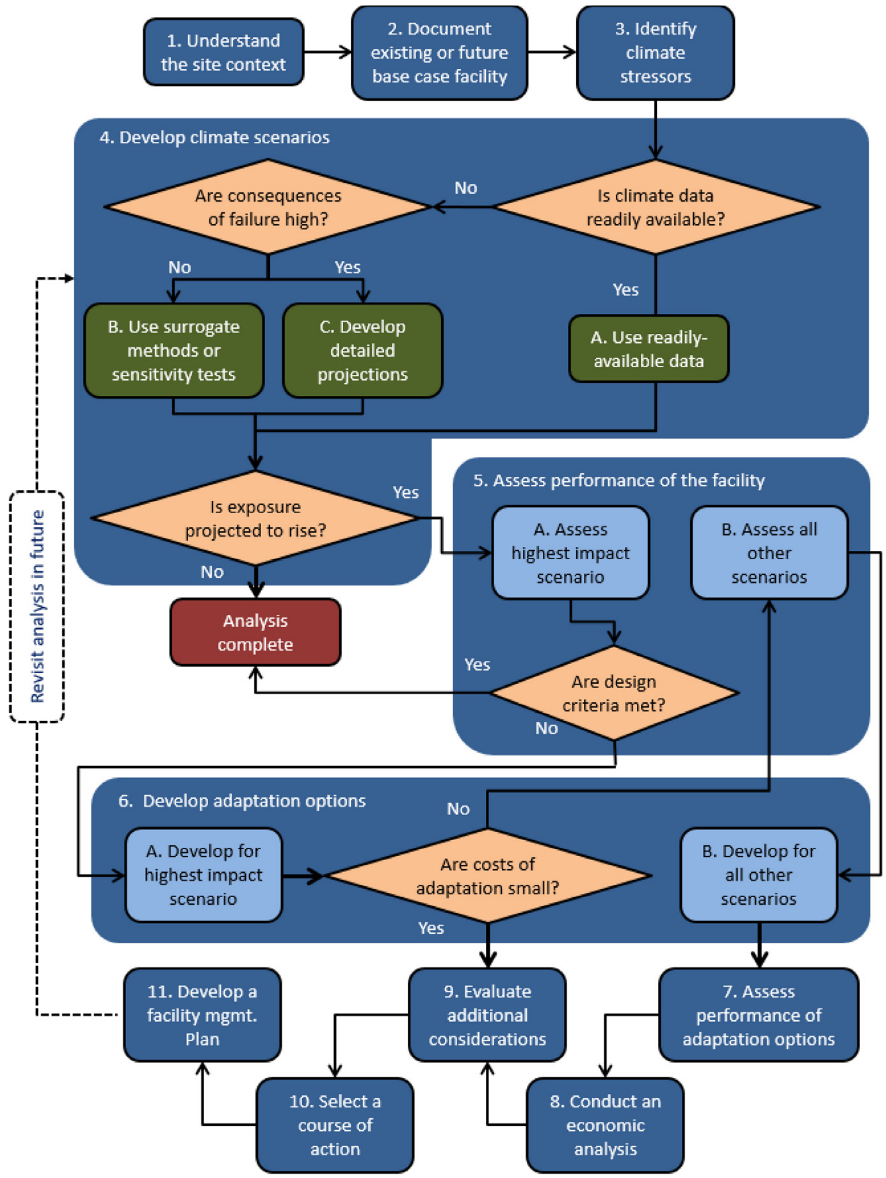
New York State DOT

In 1994, New York State DOT (NYSDOT) determined that it needed to modernize its bridge designs to have longer service lives to help reduce future rehabilitation and replacement costs. Prior to this effort, the agency designed bridge decks to for a 50-year service life with a planned rehabilitation at year 35. The goal for this effort was to double the bridge deck design life to 100 years with a planned rehabilitation at year 75. The NYSDOT Materials Bureau investigated the major causes of bridge deck deterioration and determined that the primary cause of failure was corrosion of the reinforcing steel due the intrusion of chlorides from winter maintenance activities. Upon further investigation, it was determined that the chlorides were penetrating the bridge decks both through cracks and the natural porosity of the concrete. As a result of this research, the agency began a research and development effort to design a new standard concrete mix design that had lower permeability, higher resistance to cracking, and was pumpable to support standard bridge deck construction practices.

The result of the Materials Bureau's effort became NYSDOT's "Class HP" concrete, which utilizes fly ash (a byproduct of electric power production) and micro silica (a byproduct of electric arc furnaces used in manufacturing) to replace some of the Portland cement in its standard bridge deck concrete. These new materials are finer in size than cement particles, resulting in well graded denser packing of particles in the concrete, which reduces permeability. Class HP also creates less heat while it cures (or hardens), which reduces the occurrence of thermal shrinkage cracks when the deck cools. In 1997, Class HP became NYSDOT's standard concrete mix for bridge decks. By using a failure mode analysis to identify the primary causes for bridge deck deterioration, NYSDOT could use new materials technology to address those causes and significantly lengthen the design life of its bridge decks.

process. The key difference between applying the ADAP process to developing a life-cycle strategy, as compared to a project, is in step 1. Understand the site context. When applied to a project this step is focused on a specific physical location, bounded by the project limits. When applied to developing a life-cycle strategy, the site context will likely be broader to an area that is expected to be subject to a given environmental change, such as increasing seasonal temperatures, or sea level rise. Once the proper context is established, the process steps can be followed to evaluate potential strategic adjustments that will allow life cycle management practices to account for the anticipated effects of the environmental change.

Figure 4.6 Decision Tree of the ADAP Steps



Source: FHWA. 2016. TEACR Engineering Assessment. Adaptation Decision-Making Assessment Process (ADAP). FHWA-HEP-17-004

Practice Example

Developing a Resilient Life Cycle Strategy for Pavements

Maine DOT

Maine is a cold-weather state with soils that are susceptible to severe frost conditions during winter months. In cooperation with FWHA and its Transportation Engineering Approaches to Climate Resiliency (TEACR) effort, Maine DOT undertook a project to assess the impacts of changing climate on the performance of pavements and develop strategies to offset those changes. The study looked at anticipated changes in both temperature and precipitation over the course of the 21st century. The study followed the ADAP process as shown in figure 4.6. The study indicated that anticipated climatic changes will lead to moderate changes in pavement performance. The study identified both engineering and operational adjustments Maine DOT can adopt to address these changes. The full report can be found on FHWA's website at: https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/me_freeze_thaw/

Section 4.2

Common Life Cycle Management Approaches for Transportation Assets

All infrastructure assets are designed to have a certain functional service life. However, there are major differences in how assets deteriorate (physically or in performance), the available treatment options to address deterioration, and different levels of consequence in terms of operational performance that arise, if deterioration is not addressed. In selecting a life cycle management approach for an asset-class or sub-class, an agency must understand asset deterioration, performance, and risk over time and determine what decisions need to be made throughout the asset's service life to ensure that the asset is managed effectively. In turn, the management strategies affect the supporting data that must be collected and analyzed.

There are many different criteria that can be used to manage assets and establish life cycle strategies. Performance can be measured in many ways, but with transportation infrastructure, asset condition is typically used either as the measure of performance, or as the measure of an asset's ability to provide the desired function, for example, carry the designed traffic capacity safely under design conditions. Additional information on performance management and performance criteria is provided in Chapter 6.

Depending on the criteria for performance, the available performance data, and the risk of asset failure, agencies will typically choose a standard approach to establishing a life cycle strategy for a given class or subclass of assets. Life cycle strategies describe the types of actions to be applied to an asset throughout its service life, including activities such as maintenance, preservation, and rehabilitation. This section describes how life cycle management is applied to transportation infrastructure assets to assist in selecting an effective approach for any class of assets. This section has two parts:

1. **Life Cycle Management Approaches.** Several approaches are available to agencies for managing assets throughout their life cycle. These approaches differ in the events, or situations that trigger work, the practices or analyses used to identify those triggers, and the data needed to support the approach.
2. **Determining the Most Appropriate Life Cycle Management Approach.** Agencies can select an approach to life cycle management for each asset based on how the actions that can be taken to prevent or correct deterioration, and the consequences of asset failure.

Life Cycle Management Approaches

Different types of assets require different management approaches to operate effectively and provide the expected level of service. This section introduces common management approaches used by transportation agencies to appropriately manage asset service life at both a network and asset level.

Virtually all transportation infrastructure assets are designed to have long service lives, lasting years or even decades. This means life cycle management must include long-term predictions that come with inherent uncertainty. Further complicating matters, the condition or performance of some assets may be difficult, expensive, or impossible to discern. This is most common with geotechnical assets or hidden elements on complex structures. Addressing this uncertainty requires integration with the agency's risk management practices, and consultation with technical experts, such as hydraulics and geotechnical engineers. Risk management practices are discussed in more detail in Chapter 5. This section highlights how uncertainty should be considered when selecting a management strategy to maximize service life and address risk.

Condition-Based Management

A condition-based management approach is the life cycle management approach that is the most commonly associated with asset management at U.S. transportation agencies. In condition-based management the condition of an asset is measured, and used to forecast and identify the onset of failure. Maintenance and preservation activities are identified to address the failure and restore or extend service life. While the objective of asset management is to support the reliable performance of the asset, the performance measures most commonly used for physical assets are condition-based. Agencies that are very advanced in their asset management practices may be able to apply the condition-based management approach to other aspects of asset performance.

Condition-based management relies on the collection and analysis of asset condition and defect data. This data is then used to understand the current state of individual assets and when aggregated is used to predict the future condition state of similar asset types. When linked with intervention data and condition threshold information, the future impact of potential actions can be assessed, all with the view of optimizing an asset's service life cost-effectively. Accordingly, a condition-based management approach combines condition monitoring with performance predictions and knowledge of preventive or restorative actions, to establish a cost-effective life cycle plan. The condition-based management approach can be applied to simple and complex assets, groups of single assets or a whole network. In a network perspective, components could be individual assets such as pavement segments and bridges and at a project level, components could be elements of individual assets.

Interval-Based Management (Age Based)

Interval-based Management is most commonly applied to operations assets (striping, signs, guardrail), where just an inventory is maintained. Condition assessments may not be financially feasible or practical. Additionally, these assets are often related to compliance, meaning their condition state either meets a specific standard, or does not. With interval-based management, asset performance data or manufacturer's suggested life estimates are used to establish a time interval representative of the service life beyond which the cost of asset failure outweighs the cost of replacement. The service life being the average life that all assets or components of a type are expected to last. Cyclically applied interventions can also be classed as interval-based management strategies, as there is fixed period between a set of predefined actions that have to be taken. An interval-based approach is most commonly applied to manufactured assets with highly uniform performance levels. It is less applicable to assets constructed on site or long-lived complex assets where there is a greater level of uncertainty surrounding the expected life of the asset. Examples of the types of assets that are often maintained on an interval-based approach are signals, ITS equipment, and other mechanical and electrical related items.

Reactive Management

Reactive management unlike condition or interval maintenance does not use forecasting to understand the likely timing of an intervention. Accordingly, reactive management excludes all or most actions to address asset condition or performance, until the asset reaches an unacceptable condition state. The condition state may be influenced by accumulated deterioration or a specific event, like a crash or intense storm. Reactive-management is commonly applied to low-value or less critical assets, redundant assets, or assets for which failure represents an acceptable risk. To create a reactive-based management strategy, minimum acceptable condition thresholds, must be defined. Reactive management strategies often require an agency to have a mechanism to deliver required work within a specified time frame, to avoid unacceptable levels of risk. This may include properly staffed and equipped in-house maintenance forces or "stand-by" contracts, so work can be dispatched and delivered quickly. Examples of assets managed using a reactive-based approach include fences, brush, lighting, raised pavement markers, impact attenuators, and rockfall.

Practice Example
Overhead Sign Structures – Condition-Based Management

Indiana DOT

Overhead sign structures are critical to safe and effective highway performance since they support signs, cameras, sensors and other equipment in support of routine and emergency operations. These structures typically have long service lives, but failure risk exists if they are not maintained. Indiana DOT found that failure to their overhead sign structures could be effectively mitigated through routine, real time condition monitoring and condition forecasting for predicting failure. Therefore, the Indiana DOT uses a condition-based approach for maintaining its overhead sign structures.

Indiana DOT's condition-based maintenance approach involves the steps listed below to ensure the overhead sign is installed corrected, material specifications are met, and the connection to the ground is secure:

- Professional engineers perform inspections
- An asset inspection report is developed
- The asset inspection reports are submitted to the districts
- The districts review the reports and prioritize work activities
- Work orders are developed to address the highest-priority needs
- In-house crews or local contractors perform the work

As a result of the DOT's condition-based maintenance approach, the department realized an increase in the amount of collaboration between districts and an improvement in how overhead sign structure repairs and replacements are monitored and prioritized.

Source: FHWA (2019). *Handbook for Including Ancillary Asses in Transportation Asset Management Programs* (pending publication in 2019).

Selecting the Right Management Approach

The selection of a management approach considers the mechanisms that lead assets to fail to provide their required or desired service, the consequences of failure, available intervention options and related costs.

Factors for Comparing Life Cycle Management Approaches

Failing to achieve a service level target requires an intervention, or reassessment of the reasonableness of the target. If improvement is required, selecting a management strategy is a function of where performance is insufficient. Safety improvements can reduce crash rates, additional lane capacity can improve travel time reliability, operational enhancements can improve emergency response rates and road availability during inclement weather. Where condition is below target, at a network or corridor level, interventions may be required in multiple areas.

Selecting interventions to achieve condition targets for an asset class or subclass is a data-driven, risk-based process. It evaluates what circumstances lead to asset failure, the subsequent consequences of failure, the options available to avoid failure and their costs. Costs should include the cost to monitor/analyze/ manage an asset in addition to the cost to repair. Based on an understanding of these factors, an agency can determine what strategy will be the most appropriate. The three management strategies introduced in the previous section are incorporated into Table 4.2 along with summaries of the various factors used to compare the approaches.

Reliability Centered Maintenance

Several of the principles described in this section are based on a Reliability Centered Maintenance (RCM) approach, a technique that is sometimes used by an agency to identify the most appropriate management method. Looking at an asset or asset class from an RCM perspective helps to select a management approach based on safety, operational and economic criteria. RCM is commonly applied to complicated assets that may require a range of management approaches for different components of the asset.

The RCM process has its roots in the aviation industry related to the mechanical components of aircrafts, but has been adopted across multiple industries for mechanical, electrical and infrastructure assets. Within the highways industry RCM has been considered for ITS assets. More information on the use of RCM for ITS assets has been published by Austroads (2016): Reliability-centered Maintenance Strategy and Framework for Management of Intelligent Transport System Assets.

RCM considers seven fundamental questions to select the most appropriate management approach for a set or type of assets (SAE International 2009). These questions can be applied to the selection of life cycle management approach. Based on

The term Reliability Centered Maintenance is defined by SAE International. While the use of the term maintenance in this instance does not align with use of the term in the remainder of this guide, it is used here to avoid confusion in regards to the title of the published standard.

Table 4.2 Comparison of Management Strategy Approaches. Adapted from SAE International 2009

Management Approach	Condition-Based	Interval-Based	Reactive-Based
Decision Making (Intervention) Approach	Selects intervention based on a forecasted condition exceedance interval.	Asset is treated based on a time or usage basis whether it needs it or not.	Treatment is performed to fix a problem after it has occurred.
Data Needs	Inventory information (Asset / Component) Historical condition and expert data – deterioration curves Current condition and defect data Historical Intervention and cost data – intervention strategies. Asset / component type and material data Intervention thresholds for condition	Inventory information (Asset / Component) Asset / component age. Remaining useful life of asset / component. Timing and type of last action. Interrelationships of different interventions, and how they affect the selection and timing of down-stream actions	Inventory information (Asset / Component) Current Condition data. Intervention thresholds for condition. Historical cost data
Life cycle Planning Expectations	Require the ability to understand the effects of different funding strategies. Wish to forecast the future condition state of the network or specific asset classes. Wish to minimize the life cycle cost.	Wish to gain an understanding of the typical average cost to manage the network or specific asset classes	General costs estimates based on experience. Limited need to actively manage the asset.
Considerations	Cost of collecting and analyzing condition information and developing forecasting models.	Diminished cost effectiveness / efficiency compared to condition modelling. Does not support knowledge development of asset behavior (inhibiting the move to more cost-effective regimes).	Often considered immature but is appropriate for assets if only minor consequences occur from a service disruption.
Typical Usage cases	High risk / criticality assets or risk must be more actively managed. Large portfolios or high value assets of similar construction forms Scenario planning is required Long-lived assets that can have numerous management approaches applied to them. More advanced asset management planning is required Cost uncertainty over time must be assessed (stochastics modelling)	Moderate or low risk assets. Mandated manufactures management regimes or Short-lived assets Buried assets where condition data is hard to obtain. Assets where the cost to collect condition data is expensive relative to the maintenance activity that is required	Low risk or criticality assets. Assets where the effects of accumulated defects are not critical to their functionality. Assets that are likely to be subject to unforeseen events or impairment e.g. barriers or light poles.

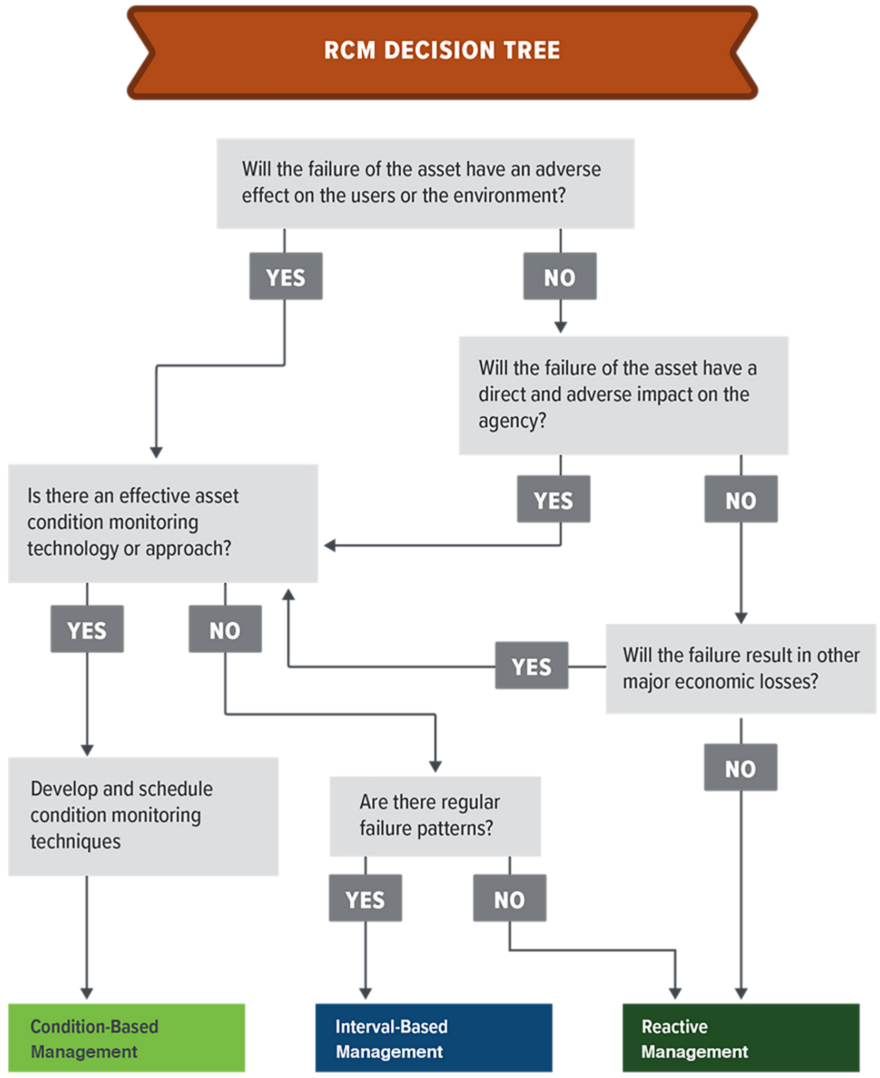
Source: Adapted from SAE International. 2009. *Evaluation Criteria for Reliability-Centered Maintenance Processes.*

the responses to these questions, an agency can determine what maintenance approach, for which parts of the asset, will maximize the likelihood of an asset performing its desired function for the lowest practicable cost. These questions are as follows:

- What is the item supposed to do and what are its associated performance standards?
- In what way can the asset fail to provide the required functions?
- What are the events that cause each failure?
- What happens when each failure occurs?
- In what way does each failure matter?
- What systematic task can be performed proactively to prevent or diminish to a satisfactory degree the consequences of the failure?
- What must be done if a suitable preventive task cannot be found?

RCM can be presented in a decision tree to aid agencies in selecting the best management approach. Agencies can also customize the questions and decision tree to meet their specific need. Figure 4.7 represents a portion of a decision tree customized to select the appropriate management approach for ancillary highway assets. By applying these questions to an asset class, an agency can prioritize asset classes for monitoring and active management. An agency can also determine which assets present limited risks to system performance and can be managed through less expensive means.

Figure 4.7 Maintenance approach decision tree



Source: FHWA. 2020. *Prioritizing Assets for Inclusion in Transportation Asset Management (TAM) Programs.*

Section 4.3

Managing Assets Over Their Life Cycles

This section provides guidance on applying the appropriate management approach to develop life cycle strategies. The management approaches introduced in the prior section each require different practices, tools, and data to implement.

This section has three parts:

1. **Managing Assets Using Condition Based Management.** Applying a condition-based approach requires quality data to support performance modeling. Models need to reliably forecast future conditions so appropriate actions can be planned and delivered at the right time.

2. **Managing Assets Using Other Management Approaches.** Many asset classes do not require the complexity of condition-based management. However, alternative approaches have their own requirements to ensure the desired level of service is reliably provided.

3. **Implementing Life Cycle Management.** Implementing new asset management practices and tools requires organizational, procedural, and policy changes. This section builds on material in chapter 2 to discuss specific steps encouraged for successful implementation of life cycle management.

Managing Assets Using Condition Based Management

The condition-based management is the most complex of the approaches introduced in Section 4.2 and requires a commitment to the collection of reliable inventory and condition information over an extended period and the of condition models to predict future deterioration to evaluate the type and timing of various treatment actions in terms of risk and performance.

Using Computerized Management Systems to Optimize Life Cycle Management

For condition-based analysis, computerized management systems are valuable tools for evaluating life cycle strategies. Computerized systems support the larger life cycle management process by providing relevant, reliable information and analysis results to decision makers at the right time.

Condition-based management is common for pavement and bridge assets. Often pavement and bridge decision making is supported by a computerized system that is used to support optimized life cycle management. The results from this analysis provide insights into optimal life cycle strategies for all network assets or for a specific group of assets. These models can be configured to include the effects, maintenance, preservation, rehabilitation, and reconstruction actions. Depending on the type of condition-based modeling approach, uncertainty can also be included.

Various life cycle scenarios can be generated by modifying one or more variables in the analysis. By running multiple network-level scenarios and comparing the results, pavement and bridge management systems can identify viable life cycle strategies and help an agency select the strategy that best achieves the stated objectives.

More information on the use of pavement and bridge management systems is available in the FHWA document, *Using a Life Cycle Planning Process to Support Asset Management: A Handbook on Putting the Federal Guidance into Practice*. Life cycle planning is a required component of risk-based TAMPs developed by state DOTs (23 CFR 515), that uses computerized asset management systems to establish long-term life cycle strategies for pavements, bridges and other highway assets. NCHRP Report 866, *Return on Investment in Transportation Asset Management Systems and Practices*, provides an assessment of how state DOTs have implemented asset management systems, including practice examples. The end of this section includes a how-to guide for using a pavement management system for life cycle planning, a requirement for risk-based TAMPs developed by state DOT's for pavements and bridges on the National Highway System (23 CFR 515).

These computerized systems are designed to develop network-level scenarios for analyzing the impacts of different program variables over long periods of time. Typical pavement management scenarios will cover 10 to 40 years, while bridge management scenarios may need to cover 100 years or more to ensure inclusion of multiple life cycles within the scenario.

Various life cycle scenarios can be generated by modifying one or more variables in the analysis. By running multiple network-level scenarios and

Long Term Analyses

It is good practice to run forecasting analyses for a time period 1.5 to 2 times longer than the time period of interest. Doing so provides long-term context to the analysis results in the last year of interest. Without extending the analysis beyond the timeframe of interest, decisions made in the final year may introduce risks or trends in subsequent years that would be unknown to the decision makers. Because life cycle management includes the full asset life cycle, it is recommended that these analyses are run beyond at least to the point of a recommended reconstruction for an asset that is new in year 1 of the analysis.

Practice Example

Use of a Pavement Management System to Establish a Life Cycle Strategies

Ohio DOT

As required under MAP-21, Ohio DOT conducted a risk assessment to identify the most significant threats and opportunities to its pavements and bridges. The analysis revealed that anticipated flat revenues, combined with the annual increases in cost to pave roads and replace bridges, would lead to significant reduction in conditions without changes to existing practice. The potential deterioration in pavement and bridge conditions were expected to significantly increase future investment needs due to the increase in substantial repairs that would be required.

Following the risk assessment, a life cycle analysis was conducted. The analysis found that by focusing on the increased use of chip seals and other preventive maintenance treatments on portions of the pavement network, the annual cost of maintaining the network could be reduced. A life cycle analysis for bridges showed similar results. The bridge analysis found that with just 5 percent of the NHS bridges receiving a preservation treatment annually, the DOT could reallocate $50 million each year to other priorities. The investment strategies outlined in the TAMP and the changes made to the DOT's existing business processes enabled the agency to offset the potential negative impact of the anticipated flattened revenue projections.

The differences in the adopted life cycle strategies are compared to the past strategies in the Figure. Although the total number of treatments applied over the analysis period increases, the annual life cycle cost decreases because of the reduction in the number of rehabilitation strategies needed.

Ohio DOT's Pavement Preservation Strategy Comparisons

Source: *Ohio DOT Transportation Asset Management Plan.* 2018. http://www.dot.state.oh.us/AssetManagement/Documents/ODOT_TAMP.pdf comparing results, pavement and bridge management systems can identify viable life cycle strategies and help an agency select a strategy that best achieves the stated objectives.

Predicting Asset Performance

A life cycle strategy is enhanced by the availability of models and analysis tools that facilitate the evaluation of different combinations of treatment type and timing across the asset class. For this analysis a model that predicts future asset deterioration and response to treatments is required.

For condition-based approaches to managing assets, historical performance is typically used as a baseline for developing models to predict future performance. The predicted conditions are used to determine the type of treatments that may be needed over an asset's service life, so the ability to accurately predict asset conditions in the future, with and without treatment, is an essential component of asset management. Models are developed by comparing performance, typically measured as asset condition, over time with actions or treatments performed on specific assets. This means that performance is associated to the last action or treatment that impacted performance in a positive way. However, assets may also receive treatments that delay the onset or advancement of distress. As a result, most models assume assets receive some level of preventive or routine maintenance between more significant treatments. If agency practices change to delay or cease maintenance activities, assets may not perform as models predict.

Several methods can be used to estimate future asset performance, the two most common of which, deterministic and probabilistic, are described below. Additional information has been published by NCHRP (Report 713, 2012): *Estimating Life Expectancies of Highway Assets*. This report also contains guidance on selecting the most appropriate modeling approach for various highway asset classes.

Deterministic Modeling

Deterministic modeling is a common and relatively simple approach for using historic data to predict future asset performance. Deterministic models apply regression analysis to one or more independent variables, typically condition over time, and develop a "best-fit" equation to determine the rate at which asset conditions change. The independent variables are used to predict a single dependent variable, most commonly represented as the predicted condition at some point in time in asset management applications. Developing deterministic models is relatively easy but relies on quality data collected consistently over several years to produce dependable results. Deterministic models are more easily implemented as they are more readily paired with linear program solving. They also provide consistent outputs. The downside of deterministic models is the limited insight that they provide into the cost uncertainty surrounding a strategy.

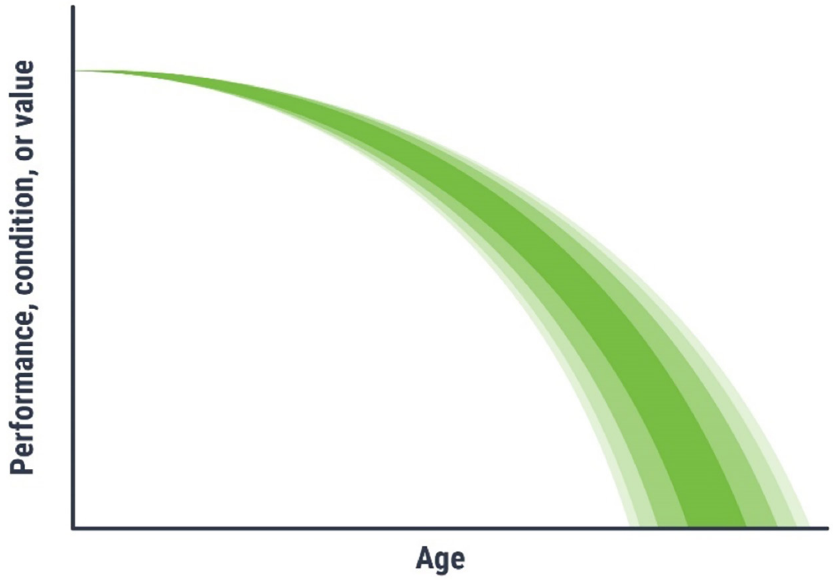
Probabilistic Modeling

Unlike deterministic models, which provide a single repeatable outcome, probabilistic models provide a distribution of possible strategies that provides insight into the cost uncertainty of plans. Probabilistic models can also more readily accept uncertainty in other variables, as represented by the shading in Figure 4.8. Given that condition changes are probabilistic, no two strategies that the model will provide are the same. This means that multiple iterations of the model with the same inputs can provide different results. Accordingly, probabilistic models are useful for setting funding limit expectations, while deterministic models help to provide insights into which projects are best to apply to specific assets.

Common approaches to developing probabilistic models are the Markov, Semi-Markov and Weibull models. Markov modeling works well for assets with condition ratings based on regular inspections. There are several ways of establishing a Markov model, but the simplest is to calculate the proportion of assets that change from one condition state to the next in any given year. These proportions are then used to develop what is known as the transition matrix. At the start of the model run, an asset "knows" its condition state. Once this is known there is then a probability it will change from its current condition state to the next in any given year. While these types of Markov approaches have been widely used, they do not necessarily model deterioration effectively, as the rate of change of condition increases with time. To address this, Semi-Markov models are used. Like Markov, Semi-Markov models have a condition transition matrix, but this is also augmented with a time selection matrix. In these models the probability of a condition jump is calculated, then the length of time an asset will remain in that condition state is also selected. Using more advanced mathematical techniques, the Semi-Markov approach can be expressed similarly to the Markov approach, but for Semi-Markov, the transition matrix changes with time. This reflects the increasing likelihood the asset will transition (deteriorate faster as its ages). Such models are typically used on long-lived assets.

A Weibull model offers another approach for modeling asset deterioration. A Weibull distribution predicts the likelihood of asset failure or deterioration as a function of age. Weibull models are particularly useful for addressing assets rated on a pass/fail basis during inspection. The Weibull model provides an additional factor meant to address the increasing or decreasing likelihood of an asset moving from an acceptable to an unacceptable state between inspection cycles. Reliability is the inverse of the probability of failure (i.e. 1 -p(f)). Reliability, like Weibull can thus be used to assess the likelihood an asset will provide the required service. The relationship between time and reliability is assessed by analyzing asset behavior to understand potential modes of failure. This analysis is a core aspect of reliability-centered maintenance, and is more typically used on short lived assets.

Figure 4.8 Example of a probabilistic model.



Source: Adapted from Transportation Research Board. 2012. *Estimating Life Expectancies of Highway Assets, Volume 1: Guidebook*. https://doi.org/10.17226/22782.

Accounting for Uncertainty in Asset Performance

Performance modeling uses historic data to estimate future performance; however, not all future events are predictable nor is past performance necessarily a predictor of future performance. This section considers the how uncertainty can be introduced into the analysis.

The unpredictability of future events introduces uncertainty into prediction models. Additionally, the amount of uncertainty tends to increase with time so their affects are compounded. As outlined in the previous section, probabilistic modeling is one approach that can be used for accounting for uncertainty, but what level of uncertainty is acceptable?

To minimize uncertainty, an agency must first understand the source of the uncertainty. A common type of uncertainty related to asset management is the behavior of the assets themselves. Due to the advancement of technology and knowledge and differences in materials and construction practices, there can be significant differences in performance between otherwise similar assets. The change in behavior can be positive, such as the introduction of epoxy-coated reinforced steel in bridge decks to delay the onset of corrosion from road salt intrusion or the introduction of Superpave and performance graded asphalt binders to reduce pavement cracking and rutting. Other changes in behavior are less easy to predict, such as the impact of salt intrusion on prestressed, post-tensioned concrete box-beam bridges. Other sources of uncertainty include:

- Weather events, e.g. flooding, drought, or freeze-thaw
- Earthquakes
- Climate change
- Traffic accidents
- Data inaccuracies
- Inaccurate models
- Poor assumptions

Practice Example

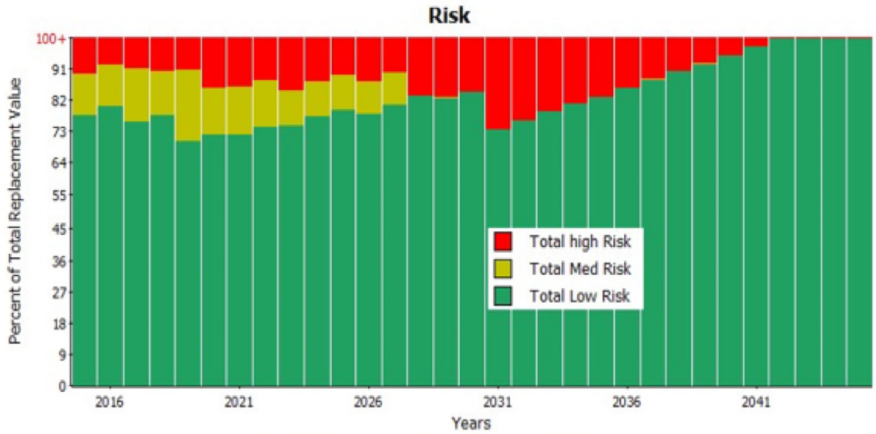
Deterministic Modeling of Culvert Condition

Halifax Regional Water Commission

Halifax Regional Water Commission (Halifax Water) has employed a deterministic modelling approach to create a plan for their storm water assets. The management system was used for long-term planning their culvert portfolio (approximately 1744 cross culverts on 3700 lane km of regional roads). The software uses deterioration curves, a temporal model periodic simulation model and has integrated Geographic Information System (GIS) capabilities. Initially the analytical objective of the model was to maximize the average condition of all the culverts and minimize the investment. Several constraints were embedded within the initial model analysis including:

- Non-Increasing percentage of culverts in critical condition
- Replace all culverts that exceed expected useful life
- Budget not to exceed scenario

The scenario analysis allowed Halifax Water to establish a minimum investment level required to bring the portfolio to an acceptable average condition state, have a reliable forecast of future condition trends, and quantify an estimate of accepted risk of failures. The figure below shows the agency's forecasted risk of failure over time based on the selected strategy and projected funding.



NBDTI forecasted culvert conditions using a deterministic model.

Uncertainty caused by variability in the data can often be addressed through the development of quality assurance plans that describe the actions an agency has established to ensure data quality, whether the data is collected in-house or by a contractor. Common quality assurance techniques include documented policies and procedures to establish data quality tolerance limits, independent reviews of collected data, and training of data collection crews. Data management strategies are discussed in more detail in Chapter 7.

To evaluate the accuracy of models and assumptions, agencies can include multiple scenarios in their life cycle planning analysis to test the impact of different decisions. This type of sensitivity analysis can be helpful in identifying areas in need of further research or developing contingency plans if the initial assumptions turn out to be inaccurate.

To understand whether time and effort should be invested in minimizing uncertainty, a risk-based approach can be used. Assuming the consequence arising from a defined issue or event remains the same, the cost in terms of data collection of reducing uncertainty can be investigated. As an example, the condition state of an asset, as determined using a visual approach, may not provide the required level of insight, which results in poor or unknowable treatment decisions. To minimize the uncertainty, extra testing can be carried out. The level of testing would be defined by the risk-cost reduction ratio. Similarly, with climate change, how much would have to be invested in studies to understand the effects on asset longevity? Thus, through risk management, an agency determines which risks are tolerable and which must be actively managed through investigations, studies other research. The risks are identified, prioritized, and tracked using a risk register (see Chapter 2). For those risks that should be managed, plans are developed to outline actions that will be taken to mitigate threats or take advantage of opportunities, as discussed in Chapter 6.

How-to

Life Cycle Planning for Pavements

A highway network consists of pavements at different phases of serviceability, and addressing the network's needs requires both current pavement condition data to identify the amount and severity of deterioration present, as well as the ability to forecast how those conditions will change over time. LCP is based on a network-level analysis that considers both economic and engineering factors to determine the most cost-effective strategies to achieve desired pavement conditions. This How-to guide provides an overview of a process agencies can follow to carry out an LCP analysis for its pavement assets.

1. Define Subsets of Network for Analysis

Define the various subsets of the pavement network that you will be analyzing. For example, an agency might analyze Interstates separately from the rest of the National Highway System (NHS), especially if the typical treatment strategies differ.

2. Establish Treatment Rules and Costs

Establish treatment rules and costs for a variety of treatment options that cover pavement needs over the life of the asset. In addition to setting up treatment rules for the types of treatments the agency normally uses, it may be useful to establish a set of rules that favor an aggressive series of preservation treatments to determine whether that strategy would result in better conditions at a lower cost.

3. Input Analysis Parameters

Input the analysis parameters, including the length of the analysis period, the treatment rules, and the estimated funding to be used, into the pavement management system. The analysis period should be at least 10 years, but may be longer to evaluate long-term impacts.

4. Run Analysis and Evaluate Effectiveness

Run the analysis and evaluate the effectiveness of the various treatment strategies established during step 2. The analysis is likely to show that strategies that include preventive maintenance treatments that keep pavements in good condition will result in better long-term conditions than strategies that include only rehabilitation or reconstruction activities when the same budget is applied to each strategy. Alternatively, the pavement management analysis could be used to show that a preservation strategy can achieve the same network conditions as a more traditional rehabilitation strategy for a lower cost.

5. Summarize Results

Summarize the results of the analysis and provide the recommended strategy for each network subset for use in developing the financial plan and investment strategies for your TAMP.

LCP for Pavements

1 Define subsets of network for analysis

2 Establish treatment rules and costs

3 Input analysis parameters

4 Run analysis and evaluate effectiveness

5 Summarize results

Applying Other Life Cycle Management Approaches

Assets that are managed using an interval-based or reactive management strategy require different approaches for planning and optimizing work than assets managed using condition. The life-cycle plans for these assets range in terms of sophistication depending on the available data.

When to Use Approaches Other than Condition-Based Management

Condition-based management requires a commitment to reliable asset condition information. The necessary level of effort is not likely to be appropriate for some assets. Some assets do not lend themselves to management using a traditional condition-based management approach. The four most common reasons assets do not fit a condition-based approach are as follows:

- The assets do not have a typical life cycle – This group of asset classes includes rock slopes or other perpetual features that do not have predictable deterioration patterns.
- The assessment of condition or performance may not be feasible – The most common type of assets in this second group are geotechnical or utility assets for which many elements may be buried or otherwise inaccessible. The absence of a rating methodology may also drive the management of assets using something other than a condition-based approach.
- The life cycle is driven by factors other than condition – There are many assets that are replaced when they are worn out or obsolete. Technology assets, which are susceptible to obsolescence at a frequency similar to their functional service lives, are examples of assets that fall into this category.
- The assets have long service lives and the failure of individual assets presents limited risks to safety or system performance – Examples of these asset classes include guardrail, gravity retaining walls, or highway lighting.
- The performance expectations require the asset to remain in near-new condition. For safety-critical assets, replacement may be necessary before signs of deterioration are evident. This is most common in risk-averse industries such as aviation. However, contractual arrangements, such as in public-private partnerships (P3), may require condition or performance targets that warrant a life cycle management approach other than condition-based.

As discussed earlier, assets that fall in these categories are typically managed using an interval-based approach or a reactive approach. Some agencies also use a risk-based approach for certain types of assets, such as rockfall management. These three different approaches are briefly explained, and examples are provided for each approach.

Alternative Life Cycle Management Approaches

Three alternative life cycle management approaches are discussed in this section. These are interval- or age-based strategies, reactive strategies, and risk-based strategies.

Interval- or Age-Based Management

Interval- or age-based strategies can be utilized for failure-critical assets, assets subject to obsolescence or assets with no or limited maintenance actions. Age-based strategies replace assets after a given time in service without regard to the asset's condition at that time. This approach can also be used for very short-lived assets, such as paint markings. Advantages include proactive minimization of failure and reduction of uncertainty in funding needs. An agency that replaces signs on a 7-year cycle or replaces pavement lane markings annually is using an interval- or age-based approach to manage its assets.

Interval-based strategies are also useful for assets that do not show physical wear, but are safety- or operations-critical.

Reactive Management

Reactive strategies can be used for assets that have long service lives and limited maintenance options. Reactive strategies can be based on the results of an on-going monitoring program or on event reporting. Examples of assets that may be monitored periodically to check that they are working as intended includes retaining walls and overhead sign structures. Assets that may be more likely to be maintained based on a report that the asset is damaged or no longer working include light bulbs and guardrail.

Practice Example
Interval-Based Approach to Managing ITS Assets

Nevada DOT

Nevada DOT recognized that the level of investment in ITS equipment (e.g., closed-circuit cameras, dynamic message signs, flow detectors, highway advisory radios, environmental sensor stations, and ramp meters) was increasing significantly and the importance of this equipment to network operations was growing. As a result, the DOT chose to establish a method of managing its ITS assets that would minimize the risk of failure and provide information to support budgeting activities. However, since the DOT had limited data on its ITS components, a process was developed that relied on the following factors to establish maintenance cycles:

- Historical performance
- Manufacturer recommended service life
- To determine the condition of ITS traffic cameras, Nevada DOT developed a transition probability matrix with four condition criteria based on the device manufacturers' recommended service life as follows:
  - **Good –** device age is less than 80 percent of the manufacturer's recommended service life
  - **Low risk –** device age is between 80 to 100 percent of the manufacturer's recommended service life
  - **Medium risk –** device age is between 100 to 125 percent of the manufacturer's recommended service life
  - **High risk –** device age is greater than 125 percent of the manufacturer's recommended service life

The transition probability matrix was used to model ITS asset deterioration and program maintenance actions over a 10-year analysis period via the use of a simple spreadsheet tool. The results of this analysis showed an interval-based approach to managing ITS assets would result in an estimated savings of $1.1 million over a 20-year period.

Source: Nevada DOT TAMP (2018)

Risk-Based Management

While all management strategies are risk-based, there are times when risk assessments are used directly as the measure to establish objectives, set targets, drive decision making, or assess progress. This approach is used when the condition of the asset does not directly represent the level of asset performance, and the potential impact of an asset's condition on system performance must be considered. This approach is commonly used for managing slopes and other geotechnical assets.

Practice Example

Risk-Based Geohazard Management Program

Colorado DOT

Colorado DOT responds to between 50 and 70 geotechnical emergencies a year. The traditional approach to managing rockfalls was based on the size and frequency of rockfalls. This approach did not consider the criticality of the facilities that could be impacted by a geohazard event. Since 2013, the Colorado DOT has used a risk-based approach to evaluate and prioritize geohazard mitigation activities based on the size of the geohazard areas and the frequency of falls. Colorado DOT's approach includes a measure of Risk Exposure (RE), which is based on three components:

- Average Annual Daily Traffic (AADT).
- Likelihood of a Vehicle Being Affected by a Geohazard Event. This metric considers site-distance, the number of previous rock-fall accidents, and a measure of how frequently a vehicle is below the hazard on a daily basis.
- Reduction Factor. This considers the effectiveness of prior mitigation actions, to reduce the RE score.

Colorado DOT's geohazards program uses the RE to allocate an annual budget of about $10 million to manage geohazards. Due to the inherent uncertainty of geohazard management, in addition to the geohazard management program, maintenance staff regularly patrol highways known to have geohazards. If a hazard requiring immediate action is identified, maintenance crews respond promptly. Using the RE for prioritization allows Colorado DOT to focus its efforts on reducing the impact of geohazards on users of the highway system.

Implementing Life Cycle Management

Implementation of life cycle management often requires agencies to review existing data sets, processes, and policies to ensure that the recommended scenarios are reflected in the projects and treatments that are programmed and constructed. Within transportation agencies, this often requires improved coordination between business units such as planning, programming, engineering, maintenance and operations. Information about strengthening organizational communication and coordination was discussed in Chapter 3.

This section focuses on the aspects of implementation that are most directly related to using life cycle management results to maximize the service lives of infrastructure assets as cost-effectively as possible. It highlights the need to evaluate agency policy, data issues, and work processes to support life cycle management.

Linking Life Cycle Strategies to Asset Management Policy

Agency policies influence the types of decisions that are made within an agency and the priority with which activities are funded. The life cycle management approach selected for each asset class will impact the type of policies, procedures, and data required to support investment decisions to ensure alignment between planned and actual work activities.

Aligning the organization to support the implementation of life cycle management strategies involves many of the same types of organizational change processes discussed in Chapter 2. As part of this alignment, an agency must ensure that it has in place the processes and resources needed to deliver the work activities required for executing the selected life cycle strategies.

Chapter 2 introduced the importance of establishing Asset Management policies to help integrate asset management at all level of an organization. An Asset Management policy can support life cycle management by establishing processes for setting realistic performance objectives and treatment strategies that focus on a commitment to sound, long-term investments. The following examples demonstrate how agencies can select a life cycle approach that supports the agency's higher-level policies.

Data Required for Implementation

All life cycle management approaches need inventory and performance information, but the extent, detail, accuracy, and precision of the required information varies greatly given the chosen approach.

Assets that are managed using a condition-based approach rely on detailed inventory and performance information so that current and future conditions can be estimated, and the benefits and costs associated with each viable strategy can be evaluated. Interval-, time-based, and reactive approaches can be performed with less detailed information about the assets. Agencies using these approaches may estimate the size and age of the inventory at early levels of maturity. Over time, the type of information available and the level of detail associated with it may improve, allowing the agency to mature in terms of its analysis capabilities.

Table 4.3 provides examples of typical management strategies for common highway asset classes and the types of information used to support each one. The information in table 4.3 reflects general trends in transportation agencies. In practice, each agency must identify the specific elements and data requirements needed to support their needs within resource constraints. Chapter 7 addresses methods of collecting information efficiently (see table 7-3) and Chapter 6 stresses the importance of keeping inventory and performance data current. Establishing data governance structures to manage asset data is also an important consideration, as discussed in Chapter 7.

Examples

Linking Maintenance Strategies and TAM Policies

The following hypothetical examples show how policy and management strategy work together to deliver transportation services and manage risks.

Reactive Strategy Example – *Agency A* has determined its guardrail inventory is generally in good condition and typically replaced as part of pavement rehabilitation projects. On average, replacements occur at least every 30 years, which is more frequent than the expected service life ranging from 40 years for cable to 75 years for concrete barrier. As a result, the agency can accept a life cycle strategy of maintaining a complete inventory and annual inspection of a random two-percent sample.

This life cycle strategy introduces the risk of a rail being damaged by collisions or other events and left in service, presenting a danger to highway users. To manage this risk, the agency implements a policy of repairing all damaged guardrail within 3 weeks of becoming aware of damage. Additionally, internal procedures are put in place to notify area maintenance managers of incidents reported through the state police accident reporting system, and standby maintenance contracts are established for guardrail repair to ensure adequate resources are available in compliance with the new policy.

Condition-Based Maintenance Example – Agency B has determined it can provide significant, long-term performance improvement in average bridge condition and service life if it can increase its investments in bridge maintenance activities like sealing concrete, repairing joints and spot painting steel. To fund this initiative, however, the agency must replace three fewer bridges on average each year. The short-term impact of this new life cycle strategy is an increase in the risk of unsafe conditions occurring on bridges that would have been replaced under the previous strategy. To overcome this risk, the agency increases the frequency of inspections on bridges exceeding the level of acceptable risk according to analysis from its bridge management system, and a series of standby contracts are established to provide rapid response of specific structural repairs to extend the service lives of poor bridges by addressing only critical structural deficiencies or risks.

Incorporating Life Cycle Management into Work Planning and Delivery

Life cycle management approaches and corresponding life cycle strategies are the means by which agencies identify the work necessary to meet their asset management goals within funding constraints. However, for those asset management goals to be met, the necessary work must actually be delivered. This requires the recommendations from life cycle analyses to be incorporated into the business processes by which the agency identifies, prioritizes, programs, designs, and delivers work. In most agencies this includes multiple business processes and funding streams. The following subsections describe how life cycle management can be incorporated into common processes within transportation agencies.

Planning and Programming

The planning process seeks to identify the set of investments that will effectively and efficiently achieve an agency's goals and objectives. As an agency alters its approach to managing assets, this may change assumptions previously influencing the planning process. Significant changes in an agency's approach to managing its assets can require updates to long-range or strategic plans. Similarly, changes in long-term objectives or plans can prompt a change in life cycle strategy or approach.

Coordination is needed between long range transportation planning, performance-based plans such as the TAMP, and programs of work, such as TIPS and STIPs (see chapter

2). In particular there is a need for alignment between the financial planning procedures and documentation between these different efforts and products. Although programs tend to be relatively short term, often 1 to 4 years in length, agencies must identify investment needs several years in advance to ensure projects can be delivered when required. Complex reconstruction or modernization projects can take 10 years or more to deliver from scoping to construction. Thus, it is important to keep planners informed of changes in selected life cycle strategies. Changing new life cycle strategies may lead to significant differences in the projects selected.

Table 4.3 Typical Maintenance Strategies and Supporting Data

Asset Type	Typical Maintenance Strategy	Typical Information Collected and Used
Pavements	Predictive, condition-based maintenance	• Linear referencing system • Segmentation with unique IDs • Inventory (e.g., width, pavement type, and other identifying attributes) • Condition data (e.g., ride quality cracking, rutting, faulting, and others) • Deterioration models • Available treatments • Treatment unit costs
Bridges	Predictive, condition-based maintenance	• National Bridge Inventory Data (NBI) • National Bridge Element Condition (NBE) Data • Vulnerabilities (e.g., scour, seismic, flood) • Deterioration Curves • Treatment options • Unit costs
Overhead Sign Structures	Monitoring-based or Interval-based maintenance	• Inventory Data, modeled after NBI • Element level condition data, modeled after NBE • Design life • Structural specification (e.g., proper bolt torque)
ITS Assets	Interval-based maintenance	• Location • Asset ID • Inventory data to identify type or class • Install date • Manufacturer recommended service life
Guardrails	Reactive maintenance	• Location • Type • Functional requirements

Source: FHWA. Handbook for Including Ancillary Assets in Transportation Asset Management Programs. 2019. Prioritizing Assets for Inclusion in Transportation Asset Management (TAM) Programs.

Project Engineering

Life cycle management is a framework for identifying the appropriate treatments throughout an asset's service life to maximize performance. Project engineering includes the processes for packaging work into contracts for delivery. Thus, project engineering is responsible for ensuring the right treatment is delivered at the right time and within the anticipated cost. Additional details on work packaging to support asset management are provided in chapter 5.

Maintaining strong internal controls ties project decisions to their impacts on anticipated asset performance. Project schedule changes may cause inappropriate treatments to be applied to assets, resulting in unnecessarily high costs or poor performance. Scope changes often lead to cost changes, and while cost changes may be addressed for a specific project, the funds added to that project would not be available to address other system needs.

Use of Agency Maintenance Forces

Effective delivery requires adequate labor capacity with appropriate training, proper equipment, and necessary materials. Changes in an agency's management approach can alter the requirements for any of these aspects of maintenance management. The necessary treatments cannot be delivered if a properly sized and equipped crew cannot be assembled. Maintenance staff cannot administer treatments for which they are not properly trained or correctly supplied. Therefore, it may be important to have maintenance management staff actively engaged in the process of identifying preferred life cycle management approaches.

Practice Example

Life Cycle Management Across a Diverse Portfolio

The City of Fredericton, New Brunswick

The City of Fredericton has, over the last 15 years, implemented several life cycle management strategies that have significantly changed how it delivers municipal services with its infrastructure. Three examples are briefly summarized below:

- Long term life cycle planning: Infrastructure accounting policy changes led to the City establishing long term replacement forecasts for each asset class to estimate the sustainable level of funding required for investment for capital budgeting. This required a complete inventory of their assets, changes in how future replacement costs were estimated, as well as changes to the analysis period used for long term planning. At least one life cycle for all assets had to be captured in the forecast horizon.
- The City implemented a Lean Six Sigma strategy to assess and improve processes and service delivery. This methodology helped identify efficiency opportunities, but also identified intervention strategies that were not previously considered in project scoping.
- The City reviewed service requirements in terms of labor and equipment required as part of the lean approach, and in some circumstances managed to create time savings or hard dollar savings or both, hence shifted resources to have different roles for service delivery. In some cases, the service delivery was contracted to external service providers.

How-to

Determining What Data Is Needed to Support Life Cycle Management

Once a maintenance strategy for an asset class or subclass (e.g. condition-based, interval-based or reactive) is selected, data is required to support the types of decisions needed to manage the asset. The type of data collected will vary based on the selected strategy and the specific decisions needed to be made to manage the asset class. The objective is to make informed, data-driven decisions on the appropriateness, timing and priority of treatment options over the service lives of specific assets. These decisions are supported by field collection of inventory and condition data, as well as the development of higher-level measures and analysis results from that data. The following sections describe methods for determining what data is essential or desirable to support maintenance decisions and the delivery of work.

Regardless of the life cycle approach selected (e.g. condition-based, interval-based or reactive), data is required to support the types of decisions needed to manage the asset. The type of data collected will vary based on the selected approach and the asset class or sub group. As described in this chapter, data is needed to support decision making about the type and timing of actions that can be taken to delay or address asset deterioration, damage, premature failure, or other performance decline. In some cases, the data can directly trigger decisions, such as accident data informing a process to repair or replace guard rail. In other cases, the data is used to support analyses that inform decision making processes, such as condition-based management.

While supporting investment decisions may be the primary purpose for collecting and managing asset data, agencies may have other purposes, such as internal or external reporting, or mandates. Agencies need to make hard choices about what data is essential to support business practices, and what data is merely desirable. Once that is determined the agency must next evaluate the benefit derived from the desirable data along with the cost and benefit of collecting and managing that data. This how-to guide provides a simple 3-step approach to identifying and evaluating essential and desirable asset data, to determine which data should be collected to support life cycle management. This approach is based on material from the FHWA document, *Handbook for Including Ancillary Asses in Transportation Asset Management Programs*, which is pending publication in 2019. The Handbook provides additional detail and several examples of data elements typically collected to support life cycle management of different assets. Additional details on data collection and management can also be found in chapter 7 of this guide.

What Data is Needed

1. Determine the Essential Data to Support the Maintenance Strategy
2. Determine Desired Data to Support the Maintenance Strategy
3. Align Business Processes

1. Determine the Essential Data to Support the Maintenance Strategy

While the management approaches discussed in this chapter vary in their degree of complexity, all three require some essential data, which can be categorized into asset class and subclass information, unique identifier information, individual asset location information and action trigger(s). The following sections describe how to determine the best means of addressing each of these data elements.

How-to

Determining What Data Is Needed to Support Life Cycle Management

Asset Class and Subclass

Asset class and subclass are defined by specific attributes that can group individual assets into sets with common management options. Asset classes and subclasses should only be defined to the level of detail that supports treatment selection, prioritization, or delivery. For example, within the asset class 'guardrail', it may be advantageous to identify subclasses of 'box beam', 'W beam' and 'PCC barrier'. However, there is likely no benefit to further dividing box beam guiderails into subclasses based on the post type or spacing.

Unique Identifier

For each asset managed using a condition-based approach, a unique identifier is required to link inventory and condition information to the specific asset in the field so it can be evaluated for work as an independent unit. This can become difficult for assets that are components of a system, such as closed drainage systems or roadside sign arrays. In these cases, there may be a need for a parent-child relationship between different asset classes. In the case of sign arrays, the support structure and each sign panel attached to it may be considered individual assets. It is good practice to have a universal system for developing unique identifiers that avoids duplicate identifiers between asset classes.

Individual Asset Location

There are many ways of determining and documenting asset location, including coordinates, linear referencing, street addresses, stationing from physical benchmarks and others. Ideally, an agency has one common referencing approach to use for all assets.

What Data is Needed

1. Determine the Essential Data to Support the Maintenance Strategy
2. Determine Desired Data to Support the Maintenance Strategy
3. Align Business Processes

Action Trigger

The selected RCM strategy will determine the type of data needed to support action triggers:

- Condition-based strategies require some measure of condition relating to both the performance of the asset and the applicability of potential treatment options. For some assets, such as culverts or drainage structures, this will require multiple data elements to describe aspects of the different means of deterioration or failure, for example sediment or structural deterioration. For other assets, such as sign panels, there may only be one measure of condition, such as retroreflectivity.
- Interval-based strategies require an age element. This could be stored as an installation date or date since last treatment. In the case of the latter, additional data elements to may be needed to describe the treatment. If this information is not known, estimates can be used at early levels of maturity. For example, if signs are generally replaced every 10 years, an agency may assume 10 percent of the inventory needs to be replaced each year.
- Reactive strategies require a means of identifying if and when an event has occurred that requires a response. Examples include identification by field staff or information from accident reports identifying damage or failure.

2. Determine Desired Data to Support the Maintenance Strategy

Data collection, storage and maintenance is expensive. It is important each data element collected has a clear purpose and use in development or delivery of work plans and projects. The following is a partial list of purposes for collecting data:

- Provide additional clarity, accuracy or precision to the essential data collected
- Support different work units within an agency, such as engineering, operations or planning

How-to

Determining What Data Is Needed to Support Life Cycle Management

- Assist in generating maintenance work orders
- Provide additional detail to manage risks
- Provide details on maintenance intervals
- Support project development through integration with other asset data sets

3. Align Business Processes

Supporting life cycle management requires the collection and management of data to support multiple business processes, including planning, design, construction, maintenance and operations. Each of these processes has data requirements and may have already been collecting some data on the asset to support those processes. It may be necessary to change business processes to use data already being collected or can be collected more efficiently. This process is described in more detail in Chapter 7.

What Data is Needed

1. Determine the Essential Data to Support the Maintenance Strategy
2. Determine Desired Data to Support the Maintenance Strategy
3. Align Business Processes

Checklist

Considerations to Support the Successful Implementation of a Life Cycle Approach to Managing Assets

The following checklist is provided to support efforts of implementing life cycle management of transportation assets. It can be used to help an agency assess whether future changes to policies, data, or business processes could advance the maturity of its life cycle management practices. This checklist should be completed for each asset within, or under consideration for inclusion in an agency's asset management program.

Levels of Service

- ☐ **Have stakeholders been identified for establishing customer-based levels of service?**
- ☐ **Has a communications process been established to understand stakeholder wants?**
- ☐ **Have KPIs been developed to address stakeholder wants?**
- ☐ **Have performance-based levels of service been established for each KPI?**
- ☐ **Have maintenance levels of service been established for the asset class to support achievement of the KPIs?**

Life Cycle Strategy Development

- ☐ **Has a clear life cycle approach been selected?**
- ☐ **Have performance or condition thresholds been established to define failure?**
- ☐ **Have performance models been developed or adopted?**
- ☐ **Have treatments been defined?**
- ☐ **Have unit costs been established?**
- ☐ **Has a life cycle plan or strategy been developed for the asset?**

Checklist

Considerations to Support the Successful Implementation of a Life Cycle Approach to Managing Assets

Business Process Implementation

- ☐ Is there a centralized individual or group who coordinates the integration and use of life cycle planning across business areas?
- ☐ Have cross-functional teams been established to communicate between asset managers and other organizational units?
- ☐ Does the agency's asset management policy provide the needed support for life cycle management of the asset?
- ☐ Is the life cycle strategy included in the development of relevant strategic plans?
- ☐ Is the life cycle strategy considered during funding allocation processes?
- ☐ Is the life cycle strategy considered during capital project prioritization, selection, or programming?
- ☐ Is the life cycle strategy considered by project development staff when making decisions on project scoping?
- ☐ Does the agency regularly review the match between planned and actual investments based on the life cycle strategy?

Data and Systems to Support Life Cycle Management

- ☐ Do staff have the data needed to establish desired levels of service or KPIs?
- ☐ Do staff have the data needed to track performance according to KPIs?
- ☐ Do staff have the data they need to develop life cycle strategies?
- ☐ Do staff have the management systems they need to develop life cycle strategies?
- ☐ Are the prediction models, treatment rules, and impact rules representative of what is included in the life cycle strategies?
- ☐ Do asset managers routinely update treatment definitions and unit costs?
- ☐ Do asset managers routinely update performance models?
- ☐ Do asset managers routinely update decision trees, or prioritization criteria?
- ☐ Are life-cycle analysis results used by planning staff during the development of strategic plans?
- ☐ Are life cycle analysis results used to support programming, or project prioritization practices?
- ☐ Are life cycle analysis results used to inform the maintenance work planning (work order) process?
- ☐ Is life cycle planning data and analysis results provided to external stakeholders?

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
Levels of Service	**Emerging**	• Customers are identified, but outreach is not formalized. • Some technical levels of service or KPIs are defined and considered when intervention alternatives are being evaluated.
	Strengthening	• Customer groups are defined and some communication practices are in place to assess wants. • KPIs are established, but may not be tightly tied to business decisions. • Maintenance levels of service are established, but there is not a tight connection to KPIs. • Technical levels of service are defined, and measured to evaluate the effectiveness of past investment and operational decisions.
	Advanced	• Customer groups are defined and clear policies and procedures are in place to assess wants. • Customer-based KPIs and maintenance levels of service are established at the strategic, tactical, and operational levels. • Agency performance is routinely measured and reported to all internal and external stakeholders.
Managing assets for their life cycles	**Emerging**	• Alternative management strategies are considered for high value / critical asset classes in the portfolio and selected based on efficiency and effectiveness of the transportation network. • Asset reliability is qualitatively considered in a systematic way for some asset classes. • Reactive and interval-based approaches that are based on risk assessments are used where appropriate. • Management strategies are periodically re-evaluated to determine if a change in management practice would be more effective. • Deployment of maintenance crews, capital projects, and network operation resources are coordinated to ensure the right interventions are occurring in the right locations, at the right time on the transportation network to deliver mobility service levels at an acceptable cost and level of risk.
	Strengthening	• Appropriate condition, interval and reactive based management strategies have been established for most asset classes. • Asset reliability is well understood and is aligned with risk tolerance in the agency. • Assets are planned, acquired and managed with an awareness of the costs, risks, and service performance characteristics over the entire life cycle. • Appropriate management strategies are established and periodically re-evaluated to determine if a change in management practice would be more effective. • Deployment of maintenance crews, capital projects, and network operation resources are coordinated to ensure the right interventions are occurring in the right locations, at the right time on the transportation network to deliver mobility service levels at an acceptable cost and level of risk.
	Advanced	• Appropriate condition, interval and reactive based management strategies have been established for every asset class in the portfolio, to support management of the transportation network efficiently and effectively. • Asset reliability is well understood and is aligned with service expectations and risk tolerance in the agency. • Strategic, tactical and operational activities directly consider alternatives that balance service delivery and investment of resources. • Reactive and interval-based approaches that are based on risk assessments are used where appropriate. • Management strategies are periodically re-evaluated to determine if a change in management practice would be more effective. • Deployment of maintenance crews, capital projects, and network operation resources are coordinated to ensure the right interventions are occurring in the right locations, at the right time on the transportation network to deliver mobility service levels at an acceptable cost and level of risk.

Maturity Scale

Aspect of Practice	Level of Maturity	Typical Agency Status
Data and Systems for Life Cycle Management	**Emerging**	• A computerized maintenance management system is being implemented / customized to better understand operations and maintenance activities within the agency. • Some basic asset modeling is used to predict asset performance in the future for financial planning purposes. • Computer management systems meeting the minimum federal requirements are implemented and used for compliance.
	Strengthening	• A computerized maintenance management system captures operations and maintenance costs within the agency and assigns these to asset appropriately. • Appropriate probabilistic and deterministic modeling techniques are used to predict asset performance for high value assets.
	Advanced	• A computerized maintenance management system captures operations and maintenance costs within the agency, and supports trade-off analysis between capital investment and operations and maintenance intervention alternative tactics • Appropriate probabilistic and deterministic modeling techniques are used to predict asset performance in the future, and inform financial planning and intervention selection.

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Link: www.highwaymqa.com

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For additional references on methods used to evaluate the condition of assets using a condition-based approach, additional resources are available through the Maintenance Quality Assurance (MQA) websites for various state DOTs. In recent years, AASHTO has been working with state DOTs to compile MQA resources on the following SharePoint site.

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Year: 2018
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Section 5.1
Resource Allocation and Prioritization Process

Section 5.2
Cross-Asset Resource Allocation Methods

Section 5.3
TAM Financial Plans

Section 5.4
Work Planning and Delivery

Chapter 5
Resource Allocation

Section 5.1
Resource Allocation and Prioritization Process
defines Resource Allocation, describes the basic resource allocation and prioritization process, and discusses how to incorporate consideration of risk.

Section 5.2
Cross-Asset Resource Allocation Methods
presents the challenges in allocating resources between multiple assets and objectives. Also, it describes basic cross-asset resource allocation approaches, including use of performance targets and formalized prioritization approaches.

Section 5.3
TAM Financial Plans
describes the steps in developing a TAM financial plan detailing sources and uses of TAM-related funds.

Section 5.4
Work Planning and Delivery
discusses approaches to grouping work for the purposes of contracting, and different delivery approaches that can be used to support maintenance work and/or capital projects.

Chapter 5
Resource Allocation

Resource Allocation is a key component of TAM. This chapter describes the resource allocation process and provides guidance on implementing a resource allocation process that makes the best use of asset data and systems to allocate scarce resources in a timely manner in support of TAM-related goals and objectives.

Key Terms

Constraint
Limitation on available resources, such as a limit on an agency's budget, available staff, or other resource.

Cross-Asset Resource Allocation
The process of assigning scarce resources to investments in transportation assets applied to cases where an allocation is made between different asset classes considering multiple objectives.

Financial Plan
A plan that describes the sources of an organization's funds and their planned uses of funds over time.

Goal
Fundamental outcome the agency is trying to attain.

Multiple-Objective Decision Analysis (MODA)
A structured approach to decision-making incorporating formal consideration of multiple, potentially competing objectives. Also referred to as multiple-criteria decision-making (MCDM) or multiple-criteria decision analysis (MCDA).

Objective
Means of achieving a goal.

Operational Target
A target that helps track the day-to-day performance of an organization.

Resource
Scarce good required by an agency to support its mission. This may include funds, materials, staff time, or other items.

Resource Allocation
The process of assigning scarce resources to investments in transportation assets.

Strategic Target
A target that an organization expects to meet at some future time and reflects their overall goals and objectives.

Tactical Target
A value an organization needs to meet to help support its strategic targets.

Section 5.1

Resource Allocation and Prioritization

Resource allocation is an interconnected process of decisions about how to allocate funds to different assets, often driven by legal requirements or a desire for better accountability. DOTs face a variety of constraints when trying to manage their assets, which makes it especially important to apply rigorous, data-driven methods when making long-term choices.

This section has three parts:

1. **What is Resource Allocation?** This section defines resource allocation and discusses factors that impact an organization's resource allocation approach.
2. **Transportation Agency Context.** This section discusses requirements that impact the resource allocation process for U.S. transportation agencies.
3. **Prototypical Resource Allocation Process.** This section presents the basic resource allocation process and presents examples of how different organizations have put this process into practice.
4. **Consideration of Risk in Resource Allocation.** This section describes how consideration of risk and uncertainty may impact the resource allocation process.

What is Resource Allocation?

In the context of TAM, resource allocation is the process of assigning scarce resources to investments in transportation assets. The assigned resources can be money, staff time, contractor capacity, equipment, or anything else that an organization requires for its assets. The investments can be capital projects, maintenance efforts, or other projects and activities that require the use of an organization's resources through various delivery methods.

To the extent an organization is focused on preserving its existing transportation assets, ideally it will make investments consistent with the life cycle management approach for its assets as described in Chapter 4. However, organizations often lack the funding, staff, or other resources needed to achieve all of their goals and objectives, and must make hard decisions about how to divide resources while considering competing needs. If resources for existing assets are systematically constrained such that the life cycle management approach is simply not achievable, the resource allocation process may need to revise life cycle strategies or the overall life cycle management approach.

The approaches used for resource allocation vary. For instance, in considering how to allocate capital funding over multiple years, an organization may need to either prioritize projects or establish an overall budget for certain types of investment, depending on the specific context. In day-to-day allocation of operations and maintenance resources, the challenge is more tactical, as a manager assesses what staff, materials and equipment are immediately available, considers both internal forces and contract capacity, and puts these to the best possible use considering current conditions and challenges.

The output of the resource allocation process could be a specific assignment of resources or a plan for what capital projects to fund. In addition, the results of the resource allocation process may impact other plans and decisions related to TAM. To the extent the process involves allocating money, a financial plan may serve both as an input to the process (by specifying what funds are available) and an output of the process that details how funds will be spent. TAM financial planning is discussed further in Section 5.3.

Once an initial set of resource allocation decisions has been made, an organization may need to reconsider the best delivery option for planned work. Issues related to work planning and delivery are discussed further in Section 5.4.

All organizations practice resource allocation in some manner, whether formally or informally. By using a structured and repeatable approach for resource allocation, an organization improves its own resilience and ensures that it will continue to succeed even as new challenges arise and personnel changes over time. This chapter outlines an idealized approach to resource allocation an organization can use to help assess how it allocates resources, and how best to improve its process.

It also describes various processes closely related to resource allocation, such as risk management, financial planning and work planning and delivery.

Transportation Agency Context

For U.S. transportation agencies, the resource allocation process is influenced by the set of legislative and regulatory requirements related to transportation planning and programming.

Since the early 1970s, U.S. Metropolitan Planning Organizations (MPOs) and state Departments of Transportation (DOTs) have been required to develop long-range transportation plans (LRTPs). These plans establish the goals and objectives of an agency and detail its high-level investment plan (not necessarily listing specific projects) over a period of at least 20 years.

Requirements initiated by MAP-21 further specify that an LRTP should be performance-based, detailing forecasted performance using a set of federally specified performance measures, and additional "locally significant performance measures" if desired. These measures include summaries of good/ fair/ poor condition for National Highway System (NHS) pavements and bridges. MPOs include performance measures and targets in their LRTPs. State DOTs have additional requirements to report shorter-term performance targets in different areas, including two- and four- year targets for NHS pavement and bridge condition.

In addition to developing LRTPs, MPOs and state DOTs are required to develop investment plans: each MPO develops a Transportation Improvement Program (TIP), while each state DOT develops a Statewide TIP (STIP). A TIP or STIP is a four-year (or more), fiscally constrained program of projects, including those that use federal funds (with some exceptions), additional "regionally significant" projects, and other projects the agency wishes to include. Because TIPs and STIPs are fiscally constrained, an agency must project its available revenue for the investments (typically capital) covered by the program over a period of at least four years, and many agencies have developed revenue projection models extending further into the future to support longer-range planning.

Beginning in 2018, again as a result of MAP-21, state DOTs are required to prepare TAMPs addressing pavements and bridges on the NHS at a minimum, while potentially including other asset classes and road systems. An agency's TAMP describes the asset inventory and its conditions, how assets are managed over their life cycles, and a 10-year financial plan for how to best maintain assets in a "desired state of good repair."

The various plans and programs cover different time periods and are intended to comply with different requirements. However, all of them may impact the resource allocation process, particularly with respect to allocation of funding for capital projects.

While these requirements are specific to the U.S., other countries have established their own planning and programming requirements, resulting in different—though frequently analogous—impacts to their resource allocation processes. Lessons learned from asset management experience in the U.S. and abroad include:

- In some cases organizations have implemented asset management programs and prepared asset management plans in

TIP Information gathered and data analyzed in the TAM process should inform resource allocation decisions that agencies document primarily in their LRTPs, TIPs, or STIPs. This is where integration and collaboration with planning and programming groups within the agency is essential.

response to legal requirements, while in others efforts to implement asset management concepts have been motivated by a desire to improve decision-making. While it is difficult to generalize, it appears that jurisdictions that adopt asset management planning by choice tend to realize the benefits much more quickly, improve service delivery, and allocate resources more effectively.

- Alignment of resource allocation to achieve goals and objectives is very important to ensure an agency advances from a traditional maintenance management approach, in which targets for asset conditions result from the available budget, to a performance-based approach in which an organization's goals and objectives help define the required level of service (LOS) for its assets, which in turn drives resource allocation decisions.
- Organizational goals ideally should not focus on assets, or their condition, but the outcomes that are desired, such as improved mobility, safety and infrastructure resilience. Changing technology (CAV, communications), social (graying populations, work from home patterns, ridesharing), economic (integrated transportation modes), may be very relevant to how resource allocation should be conducted. Agencies that make resource allocations based largely on the condition and life cycle strategies of only the existing portfolio, may face greater challenges achieving their goals, and adapting to the changing needs of their economies.
- International, and US DOT agencies that have focused resource allocation on their goals and objectives, rather than on the existing assets they are responsible for, tend to be more readily able to leverage alternative service delivery models that may present service enhancement or cost saving opportunities. These agencies agree that "We don't need to build it or own it or maintain it, to deliver mobility."

Practice Example
Resource Allocation Policy

Washington State DOT

Washington State DOT has worked closely with its legislature to adopt asset management based resource allocation policies.

The following is an excerpt from state legislation that was last updated in 2002:

"deficiencies on the state highway system shall be based on a policy of priority programming having as it's basis the rational selection of projects and services according to factual need and an evaluation of life cycle costs..."

– RCW 47.05.010

This legislation along with good business practices has made Washington State DOT have one of the most mature asset management practices and an integrated set of tools, business processes, and organizational culture to support good asset management.

Source: http://apps.leg.wa.gov/RCW/default.aspx?cite=47.05

Prototypical Resource Allocation Process

The basic resource allocation approach includes seven basic steps. Specific approaches to resource allocation differ depending on where resources are being allocated and the organizational context.

This section describes a basic resource allocation process. The resource allocation process can be used to answer three key questions:

1. What resources are required and how should they be distributed over time to best meet the long-term goals and objectives?
2. What performance targets are achievable given available resources?
3. How should resources be used in the short term to best support the goals and objectives?

The details of the process differ depending on what resources are being allocated to what investments, the timeframe and the particular circumstances faced by the organization.

A generic process is presented here as a framework for assessing the different allocation processes used by different organizations, as well as to help structure the discussion of issues related to resource allocation presented in subsequent sections of this chapter. The process is iterative; it is frequently necessary to walk through the process in order to establish a proposed allocation, review the proposed solution, and then revisit the assumptions made earlier, altogether resulting in a revised outcome.

In applying the prototypical process, it is important to consider that organizations typically have different resource allocation processes for allocating different resources over different time periods. The basic steps in the process are the same regardless of the specific context,

Practice Example
Resource Allocation Process

Michigan DOT

Michigan DOT recently introduced principles of performance-based contracting to their routine highway maintenance delivery. The focus of this initiative was on developing a better understanding of performance, providing more consistency of service, encouraging innovation adoption and identifying efficiency opportunities.

To achieve this MDOT developed performance measures for 23 non-winter maintenance activities. They then examined how these activities contributed to the objectives and community outcomes MDOT wanted to achieve (e.g. safety, reliability, economic benefit, and quality of life) and used that analysis to select six initial key measures for which targets were set to focus the effort. The performance monitoring system helped one MDOT region identify unsealed shoulders (ensuring they are even and traversable) as an area requiring improvement. They invested in additional shoulder maintenance in 2015 and from this realized a performance increase of more than 30%.

MDOT is using this performance monitoring approach to better understand the cost of improving its maintenance level of service. The agency is also identifying specific resources to focus in areas where it can achieve a more consistent and safer outcome.

TIP **Almost all agencies already have structured resource allocation processes; introducing TAM or im proving TAM practice should begin with assessing existing processes to identify areas where asset related data and TAM process analysis outputs (e.g. life cycle planning outputs) can be incorporated.**

but the details of how each step is performed may vary.

For example, in considering how to allocate resources over a period of 10 years or more, an organization might consider what funding is needed and how best to allocate funds across multiple investment categories while setting aside decisions about specific projects. In this case, the key resource being allocated is money, and the emphasis of the process will be on Step 1 – Establish Goals and Objectives and 3 – Quantify Targets. Further, in this case there may be less emphasis on Step 2 – Determine Constraints, and the prioritization performed in Step 5 may yield identification of high-level priorities rather than a prioritization of specific projects.

On the other hand, when considering how best to use staff resources and materials to perform maintenance work in the short term (less than one year), the organization would apply the process differently. In this case, the resources being allocated would include time and materials. The emphasis on the process will be on Step 2 – Determine Constraints, Step 5 – Prioritize Investments, and Step 7 – Finalize Allocation and Plans. In this case the specific allocation may not have a significant impact on the goals and objectives established in Step 1, and the prediction of future performance in Step 6 is less relevant than in the case of a longer-term allocation.

The practice examples in this section show how agencies have implemented this basic process to address different resource allocation challenges.

Practice Example
Resource Allocation Process

New Zealand Southland District Council Economic Road Network Planning

Southland District Council (SDC) manages one of the largest road networks in New Zealand. Dairy farming is critical to the economy of the local area and more broadly to the Country (SDC generates 10% of New Zealand's dairy exports). In the period 2000-2010 there had been significant expansion of the dairy farming industry and further expansion was likely. Maintenance and renewal costs were estimated to increase significantly and SDC's road rates were already among the highest in the country. SDC recognized that a new approach was necessary and they could not keep doing things the same way.

SDC developed the Economic Network Plan as an asset management approach that allowed SDC to determine where investment in the network would provide the greatest financial return to the community. The Economic Network Plan considered the following services provided by the network:

- Safety
- Road Condition (Levels of Service)
- Enable Exports
- Service Delivery
- Customer Quality

Consideration of the resources required to maintain the network led SDC to the decision that its highest volume roads would be maintained to its then-current LOS standard. These roads represented 20% of the road network but carried nearly 70% of the traffic. The remaining 80% of the network would have a reduction in standard over time. The Economic Network Plan provided the basis for this change.

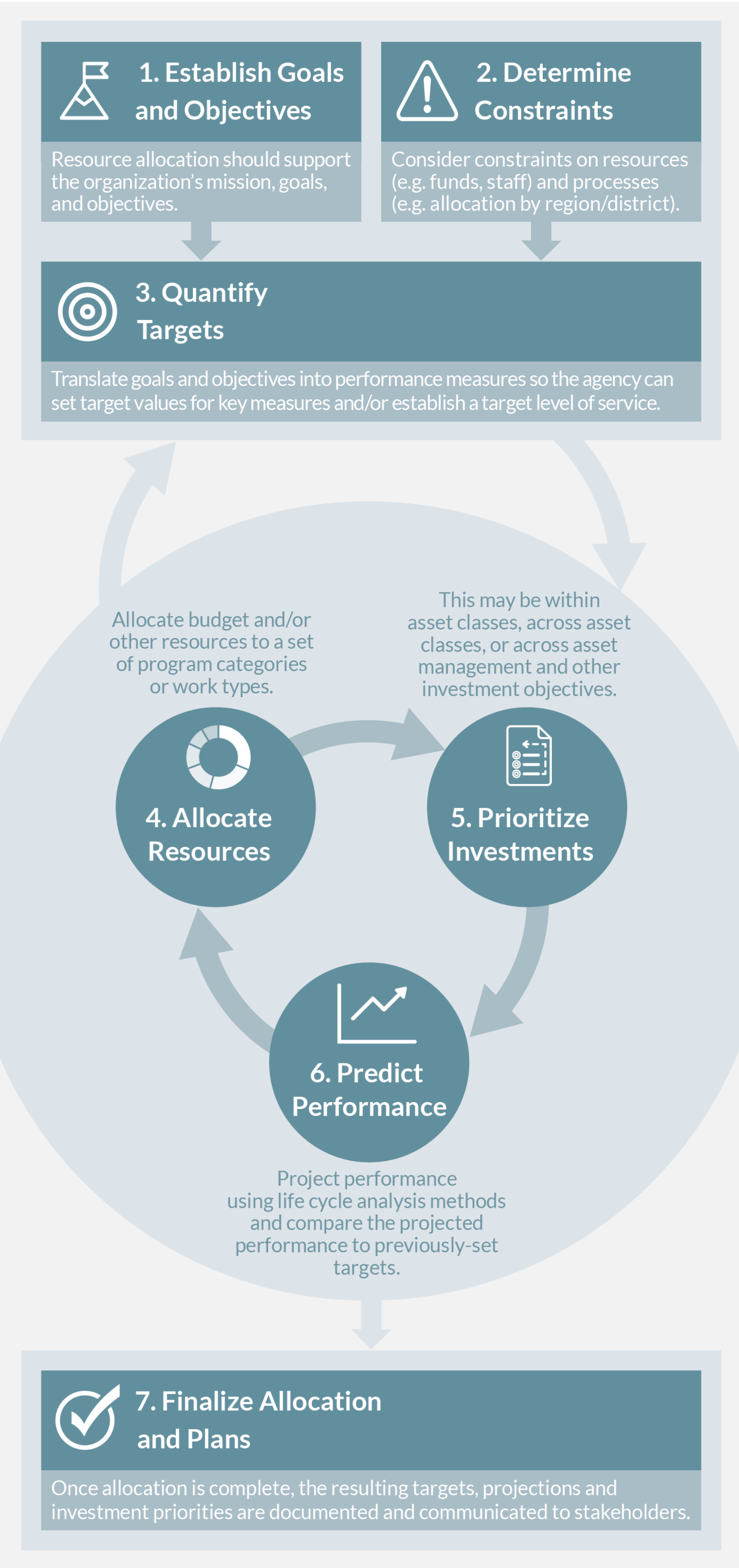
Like many agencies, the SDC was forced to take a different approach when financial constraints required change. It enabled all parties to focus on:

- Shifting from 'Engineering' to 'Customer Service Network Management' (why the service is provided)
- Managing customer expectations proactively rather than reacting to them
- Making safety a priority
- Investing in technology and information to understand, manage and integrate with HCV operators

Source: https://www.nzta.govt.nz/assets/Road-Efficiency-Group-2/docs/southlandnet-workplan.pdf

Note: For more information on this example, see the case study on the SDC's experience in the International Infrastructure Management Manual (IIMM).

Figure 5.1 The Resource Allocation Process



There are seven basic steps in the resource allocation process.

1. Establish Goals and Objectives. The mission, vision and broad agency goals are meant to guide decision-making across an organization. Goals and objectives may be articulated in an organization's LRTP and/or TAMP. Ideally, the resource allocation process should support achieving these.

2. Determine Constraints. Establish what resources must be allocated, and what the constraints on them are. Typically this will include constraints on available funds, but may include constraints on staff, contractor capacity, equipment, materials, or other resources. Further, there may be other constraints relevant to the process, such as constraints to distribute funds equitably between different regions or areas, or constraints on exactly how certain resources can be used.

3. Quantify Targets. Translate goals and objectives into specific criteria for supporting allocation decisions. Where feasible, define performance measures that quantify the level of achievement. Set target values for key measures and establish a target level of service as discussed in Section 5.4.

4. Allocate Resources. Split the budget and other resources to the set of program categories or types of work. The allocation specifies the distribution of resources between different categories or work types. The details of how this step is performed are dependent on the details of the resources being allocated, assets being analyzed, and types of investments under consideration.

5. Prioritize Investments. Determine what specific investments to make given the overall allocation of resources. This determination may be made within an asset class, across asset classes or across asset management and other investment objectives (e.g. safety or mobility) depending on how the process is structured. The prioritization should maximize achievement of the organization's goals and objectives as quantified using the measures and targets set in Step 3 subject to the constraints established in Step 4.

6. Project Performance. Predict future performance given the assumed allocation and priorities, and compare the predicted performance to previously established targets. This may result in revisions to the constraints, targets or outcomes of other steps described above. To the extent that the targets are set for asset conditions, use the life cycle analysis methods described in Chapter 4 to predict future asset condition.

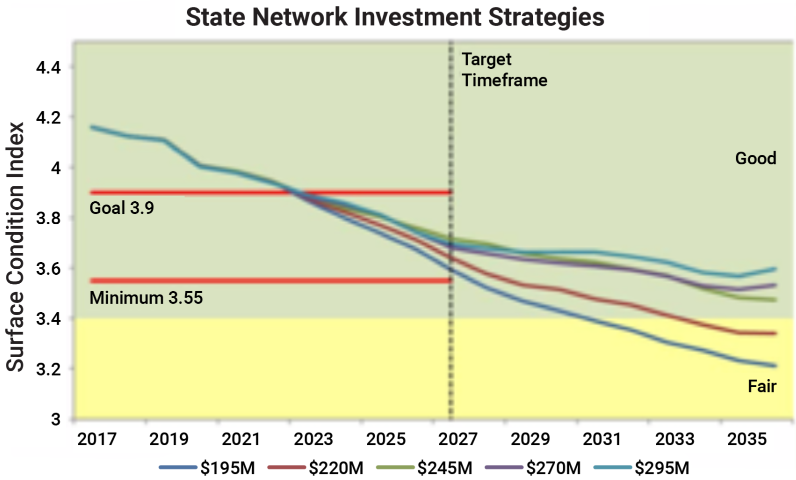
7. Finalize Allocation and Plans. Once allocation is complete, document the resulting targets, projections and investment priorities and communicate these to stakeholders. Further work may be required following completion of the formal process, such as developing maintenance plans based on the set of approved projects.

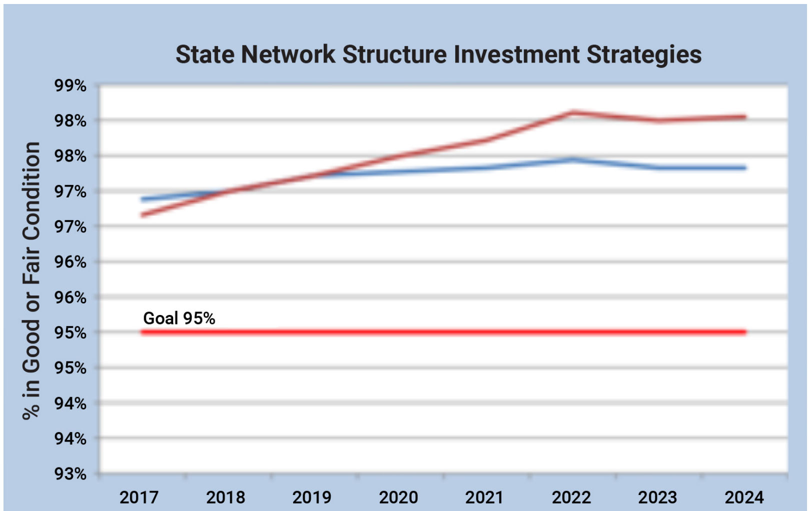
Practice Example
Resource Allocation Process

South Dakota DOT

SDDOT's agency mission is "to efficiently provide a safe and effective public transportation system." To support this high-level goal the agency sets ten-year objectives for its pavements and bridges, as well as a minimum acceptable condition for pavements. For pavements SDDOT summarizes conditions using Surface Condition Index (SCI), a composite measure represented on a scale from 0 (worst condition) to 5 (best conditions) that incorporates measures of roughness, rutting, faulting and distress indices. For bridges, SDDOT summarizes conditions based on the percentage of structures in good or fair condition, using the FHWA good/fair/poor measure for classifying the condition of a bridge.

To determine how to allocate capital funds for state-owned pavements and bridges SDDOT relies heavily on its pavement and bridge management systems. The agency predicts conditions for a 10-year period for a range of different budget levels, and then compares the predicted performance to the agency's goals and objectives. The figures, reproduced from SDDOT's 2018 TAMP, show results in terms of predicted SCI over time for five budget scenarios generated using SDDOT's Pavement Management System (PMS), and results in terms of percent of bridges in good or fair condition for two budget scenarios generated using the agency's Bridge Management System (BMS).





Given the projections as well as additional projections of pavement condition for six functional systems, the agency uses its Trade-Off Tool to evaluate the impact of different funding scenarios and recommends the funding distribution that will produce the greatest benefit. The final result of the analysis is a distribution of funding between asset type and functional system, as well as the distribution of funds between four types of work:

- Construction and Reconstruction
- Resurfacing and Asphalt Surface Treatment
- Rehabilitation and
- Safety

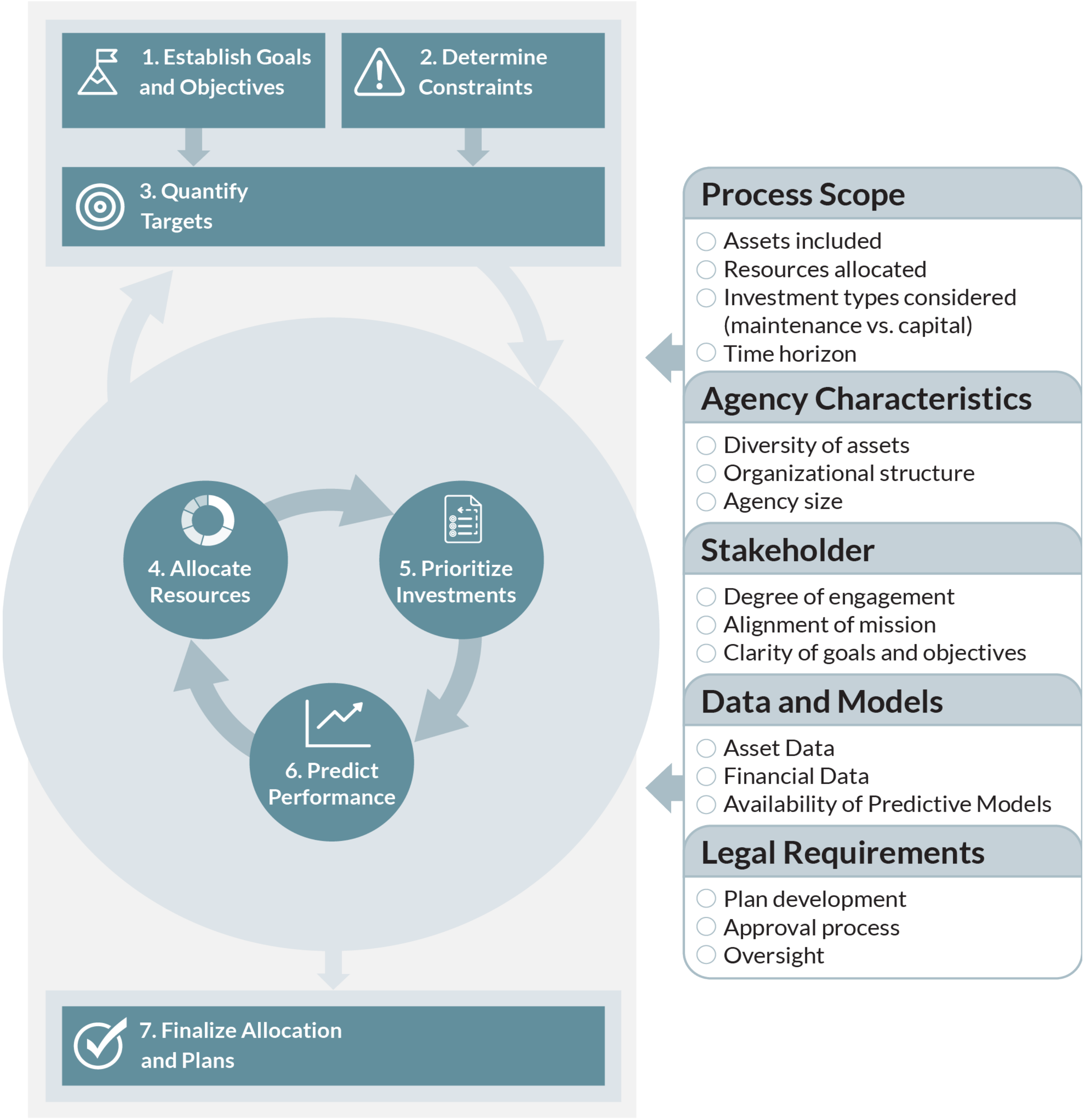
Decisions about what capital projects to perform are then made given the funding level established in the trade-off analysis.

Source: SDDOT Transportation Asset Management Plan. 2018. http://www.sddot.com/resources/reports/SDDOT2018TAMPFHWASubmittal.pdf

TIP **Although a generic framework for resource allocation is presented, agency context and other factors (e.g. legal requirements) will create the need for agencies to allocate resources in different ways.**

Figure 5.2 Factors Impacting the Resource Allocation Process

The specifics of how an organization can and should approach resource allocation depend upon a number of different factors. Understanding these factors is key in developing a successful approach to resource allocation.



Consideration of Risk in Resource Allocation

Uncertainty and risk complicate the resource allocation decision-making process. Risk management activities, including developing a risk register, are helpful in understanding and mitigating uncertainty, which in turn has implications for resource allocation.

Overview

All transportation decision-makers must contend with uncertainty. In regards to resource allocation, uncertainty is inherent in variables such as data on asset conditions and performance, future funding levels and costs, how a transportation system and specific assets will perform, and what external events or other factors may require reallocating resources. This uncertainty complicates efforts to make decisions about the future and forces agencies to be nimble so as to effectively respond to unpredictable events and evolving conditions.

In recent years, transportation and other industries have made significant progress developing improved approaches for managing uncertainty to minimize negative and leverage positive impacts. An area of focus in transportation has been in managing the risk of project cost and schedule overruns; a number of agencies have established enterprise risk management programs in order to address risk and uncertainty across their organizations. Likewise in TAM, there is increased interest in identifying and assessing risk so as to comply with both the best practices and the FHWA requirement for state DOTs to consider risk in developing their NHS TAMP.

The word 'risk' can be very context specific, meaning very different things depending on the industry and application. For instance, a financial analyst is primarily concerned with uncertainty in financial returns and the risk of incurring a significant financial loss. In the nuclear power industry, however, the focus of managing risk is on minimizing the potential for catastrophic loss that might occur from damage to a nuclear facility. As discussed in Chapter 2, in this guide risk is defined as the "effect of uncertainty on objectives" consistent with the ISO definition. This definition captures the full range of applications of risk management, and acknowledges the possibility for both positive and negative consequences of uncertainty.

The term 'risk management' is used to capture the set of business processes associated with identifying and managing uncertainty and risk. The overall risk management process is described in Chapter 2. The remainder of this section describes how this process relates to resource allocation.

Implications for Resource Allocation

While the scope of risk management may be very broad, an organization's approach to risk management and the outcomes resulting from a risk assessment may nonetheless have important implications for TAM resource allocation. Consequently, it is important to establish a risk management approach and integrate consideration of risk with the resource allocation process.

Specific possible implications of risk management on resource allocation may

Practice Example
Seismic Risk Management

Caltrans

Caltrans initiated its Seismic Safety Retrofit Program in the wake of bridge failures experienced in the 1989 Loma Prieta Earthquake. Through this program Caltrans evaluated the retrofit needs for all of the over 12,400 bridges on the State Highway System (SHS). Retrofit needs were prioritized using a multi-attribute procedure that calculated a score for each bridge considering the likelihood of an earthquake at the bridge site, the vulnerability of the bridge to collapse in the event of an earth- quake, and the impact of a collapse considering the traffic using the bridge and detour distance in the event of a collapse. Through 2014 the program resulted in retrofit of 2,202 state highway bridges at a cost of over $12.2 billion.

Source: 2018 Caltrans TAMP Practical Lessons from the Loma Prieta Earthquake (1994), p. 174-180 (https://www.nap.edu/catalog/2269/practical-lessons-from-the-loma-prieta-earthquake)

TIP Muti objective decision making is a concept in operations research that is implemented in several different forms, from simple consensus building approaches (e.g. Delphi processes) to more complex soft ware tools. In all cases, it allows consideration of more than one factor or criteria in making a decision.

include, but are not limited to:

- An organization may identify through its risk management approach areas where better data or improved processes are needed to best address a given risk, in turn impacting the resource allocation process. For instance, if uncertainty concerning future asset conditions is found to be a significant risk, this may result in efforts to improve the deterioration models in an agency's asset management systems and/or motivate data collection improvements to reduce uncertainty.
- An organization may identify specific investments of staff time and/or agency funds required to mitigate negative or leverage positive risk. Once specific investments are identified, they can be assessed along with investments in other asset/investment categories. For example, Caltrans defined a separate program for seismic retrofits as described in the Practice Example.
- If an agency's allocation of resources hinges on uncertain future values for one or more parameters, it may be necessary to incorporate consideration of uncertainty formally in the decision-making process. This can be accomplished using Monte Carlo simulation or other quantitative approaches to establish the predicted distribution of outcomes. For instance, in performing a life cycle cost analysis to select between project alternatives for a given facility, Monte Carlo simulation can calculate the range of life cycle costs predicted depending on future values for cost escalation, deterioration, or other parameters.
- In approaching formal accounting for uncertainty, an organization may define different scenarios representing the possible range of outcomes and then determine how best to allocate resources in each scenario before establishing a preferred resource allocation approach. For example, if an agency's future capital budget is unknown, a decision-maker may wish to define a high, medium and low budget scenario and determine what investments would be made in each scenario in order to most effectively prioritize given uncertainty. Likewise, a scenario analysis approach can be useful in assessing how to allocate resources for improving infrastructure resilience given uncertainty concerning future sea level rise. Typically, the decision maker will review results for different scenarios and make a subjective determination of how to allocate resources considering the relevant factors. The Practice Example describing the analysis of harbor-wide barrier systems for the City of Boston shows one such approach. Recent research in the area of Robust Decision Making (RDM) has focused on developing quantitative approaches to select optimal investments between different scenarios.

Practice Example
Analysis of Harbor-Wide Barrier Systems

University of Massachusetts

The Sustainable Solutions Lab at the University of Massachusetts Boston used a scenario-based approach to analyze the feasibility and potential risk reduction of large barrier systems across the entrances to Boston Harbor to protect the Boston area from future flooding due to sea level rise. The report included an economic analysis in which costs and benefits were predicted for 32 scenarios considering:

- Two barrier system alternatives
- Two construction time scenarios
- Two scenarios for effectiveness of the "shore-based solutions" that would be part of an integrated flood management system
- Low and high construction cost estimates
- Discount rates of 3% and 7%

It was found that if a barrier is designed to manage all the events greater than the elevation of the shore-based protection system, then the benefit-cost ratios of any barrier system are low—ranging from 0.05 to 0.33 for 7% discount rate and from 0.20 to 1.69 for 3% discount rate. These results indicate a low cost-effectiveness of barrier systems. Also, the analysis indicated that beyond a certain point, sea level rise would be such that a barrier system would no longer prove effective since the barrier would have to be closed so frequently if would mechanically fail and also cause major environmental impacts. The report further predicted costs and benefits for two alternative scenarios involving incremental adoption of a variety of shore-based mitigation approaches. It recommended an initial focus on shore-based adaptation as the most promising strategy for the City of Boston to address sea level rise because of the significantly higher benefit-cost ratios, their many co-benefits, and their flexibility to manage the uncertainties of future sea level rise.

Source: https://www.greenribboncommission.org/wp-content/uploads/2018/05/Feasibility-of-Harbor-wide-Barriers-Report.pdf

Practice Example
Risk Management

Regional Municipality of Peel

The Region of Peel is the second largest municipality in Ontario, just west of Toronto and supports two cities and a town. Peel assesses needs and priorities across a diverse portfolio of Infrastructure that supports a variety of programs and services including an arterial roads network, solid waste management, water and wastewater treatment distribution and a variety of social, health and emergency services. The Region integrated a number of inputs to enable an optimized investment methodology including a Risk Management, Level of Service, and Life cycle Management Strategies and prioritize needs across diverse infrastructure, as illustrated in the figure. The integration of these three strategies was possible through three enablers and working with all of the programs and services to model their infrastructure:

1. Establishing a consistent approach to quantifying risk – The Region evaluates the degree of risk that is currently being accepted associated with delivering service levels. Inherent risk (similar to asset criticality) and residual risk (the Region's risk objective) are established and the current level of risk that an asset presents to service delivery is also determined. The gap between current and residual risk represents the unmet funding and asset needs.
2. Establishing a normalized method to determine current level of service to assist the cross-asset funding allocation task. The adopted normalized indicator was determined to be: LOS=% of Assets Meeting LOS + (% of Assets Not meeting LOS x Average Condition of Assets not meeting).
3. Adopting a direct relationship between LOS and risk that allows for an analysis of alternative investment scenarios, and modeling techniques to optimize investment allocation. It also allows annual infrastructure evaluation based on the most current condition information and annual Asset Management Reporting.

Peel's risk-based approach to asset management is integrated with the Region's Strategic Plan and the Long-Term Financial Planning Strategy, and supports the desired service outcomes by evaluating risk against the Council approved asset levels of service. This approach provides senior decision-makers an objective way to consider resource allocation alternatives and communicate in a common language when evaluating between service areas and different asset portfolios.

Source: Peel Enterprise Asset Management Plan. 2019.
http://www.peelregion.ca/council/agendas/2016/2016-04-07-arc-agenda.pdf
http://www.peelregion.ca/finance/_media/2019-enterprise-asset-management-plan.pdf

Section 5.2

Cross-Asset Resource Allocation

The resource allocation process described in Section 5.1 can be applied to a specific asset type, or to multiple types of assets or investments. However, there are many challenges organizations face when making decisions about investments considering multiple types of assets and types of investments. Two basic approaches for helping determine how to allocate resources across asset types are defining performance targets and developing a structured prioritization process that quantifies achievement of multiple objectives.

This section has three parts:

1. **Challenges in Cross-Asset, Multi-Objective Decision-Making.** This section explores the factors that complicate resource allocation decision-making considering multiple objectives.
2. **Use of Performance Targets to Support Cross-Asset Resource Allocation.** This section describes how to set performance targets to support allocation between different asset or investment types at a high level.
3. **Use of Multi-Objective Decision Analysis for Resource Allocation.** This section describes how to develop a structured prioritization process incorporating consideration of multiple objectives.

Challenges in Cross-Asset Resource Allocation

Resource allocation decisions considering multiple objectives is difficult due to a variety of factors. Competing objectives, data limitations, and uncertainty complicate the resource allocation process.

In determining what work to perform across all assets, an agency is faced with the basic problem of multi-objective, cross-asset decision-making. Typically an agency must, either implicitly or explicitly, determine how to divide scarce resources between different asset types, and in so doing try to accomplish a variety of different objectives.

The basic process described in Section 5.1 is applicable whether the resource allocation process concerns a single asset or multiple assets. However, there are extra challenges inherent when dividing resources among multiple types of assets or types of investments. Making resource allocation decisions considering multiple objectives is made more difficult by a variety of challenges, including but not limited to:

Competing Objectives. Fundamentally, a transportation agency seeks to improve mobility while maximizing the safety of the transportation system, minimizing negative impacts to the environment and society, and making best use of limited funds and other resources. It is difficult to quantify these as well as other competing objectives and often hard to reach consensus on what achievements should be prioritized when determining how an agency measures the progress of different areas to support a decision.

Data Limitations. A structured approach to resource allocation requires data. Ideally, an agency has detailed, quantitative data on existing conditions, the scope of a proposed investment, and what the effects of an investment are likely to be. However, obtaining data and projecting future conditions can be costly, and the decision to proceed with an investment must sometimes be made before detailed data is available. Often it is necessary to use qualitative data or estimates in lieu of quantitative data.

Uncertainty. Transportation investments are intended to make improvements in the future, but there is always uncertainty concerning future asset and system conditions as well as how assets will perform and what external risks may impact the system.

Structuring the resource allocation process to address multiple types of assets or investments requires particular focus on two of the steps illustrated in Figure 5-1: Step 3 - Quantify Targets and Step 5 – Prioritize Investments. Different approaches to cross-asset resource allocation tend to focus on one or the other of these steps.

For instance, a process focused on defining targets is premised on the fact that most asset management systems model different asset classes separately, using different deterioration models, treatment rules and benefit calculations. Different systems and approaches are also used to analyze different types of investments. It is possible to perform separate analyses for each asset or investment type that consider what results will be obtained depending on the overall investment level or other variations in resource allocation. Decision makers can then review the results of the different analyses to determine how to allocate resources at a high level. Once an overall allocation is established, different approaches can be used for prioritizing investments by asset or investment type.

In contrast, with a process emphasizing prioritization, the focus is on identifying and prioritizing specific candidate investments. The prioritization approach helps determine which investment is most desirable considering the organization's goals and objectives, and the predicted outcomes of the investment. In this case it is not necessary to perform asset-specific analyses, and it is possible to define projects that address multiple types of assets and investments that cut across predefined types. For example, a corridor project could include work on existing pavement and bridges, as well as intersection improvements that improve safety and mobility. However, an organization implementing a cross-asset prioritization approach must consider how to quantify its different goals and objectives, and explicitly weigh progress in one area versus another.

In practice, most agencies use an approach that involves both setting performance targets and prioritizing specific investments. The following subsections provide additional details on use of performance targets and multi-objective approaches, and provide examples illustrating emphasis on each of these areas.

Use of Performance Targets to Support Cross-Asset Resource Allocation

A basic approach allocating resources across multiple types of assets is to define a set of performance targets by asset type. Development of TAM performance targets should be supported by data and the life cycle management approach described in Chapter 4. A resource allocation process that includes multiple types of investments, such as safety and mobility, may incorporate other targets, as well.

Target-setting is the process of setting specific values that an organization expects to achieve for a set of performance measures. Target-setting is important within the broader area of performance management, introduced in Chapter 2. Setting performance targets is consistent with best practice in asset and performance management. In its Transportation Performance Management (TPM) Toolbox, FHWA describes the benefits of setting performance targets:

- Driving a conversation about current conditions and how to achieve future outcomes
- Creating a method for evaluating processes currently in place, particularly data quality and measurement definitions used by the agency
- Guiding the prioritization and allocation of resources
- Enabling assessment of strategy effectiveness by focusing on linking goals, objectives, and measures to policy and investment decisions
- Forming a powerful argument for additional or alternative investments
- Managing expectations by clarifying what outcomes are desired

It is important to note that an organization may set targets at a strategic, tactical or operational level to support different applications:

- A strategic target is one which an organization expects to meet at some future time and reflects the agency's overall goals and objectives. For instance, an agency's long-term target for overall pavement condition is an example of a strategic target.
- A tactical target is a value an organization needs to meet to help support its strategic targets. For instance, to support a high-level target for pavement condition, an agency might set a tactical target to perform a specific amount of repaving work per year in each district.
- An operational target is one that helps track the day-to-day performance of an organization, such as the average time to respond to an incident. Operational targets are often used to support continuous improvement in standard operating procedures and process improvement tracking and monitoring.

The TPM regulations initiated by MAP-21 have specific requirements for state DOTs and MPOs to set performance targets for NHS pavement and bridge conditions, as well as for other areas outside of TAM, such as mobility and safety. In these regulations, a target is defined as the value for a performance measure the agency expects to achieve given available funding, rather than a desired or aspirational value. The benefits of target-setting are equally applicable regardless of whether an agency is setting targets specifically to comply with FHWA requirements or for other purposes.

There is as strong tie between target-setting and resource allocation. A target can both inform what investments an agency needs to make and help communicate the expected results of an investment strategy.

When an agency sets strategic targets to support allocating resources, the process is typically iterative. For instance, an agency might first determine the desired level of performance that best supports its goals and objectives, such as the overall performance that would result from maintaining all assets in good repair or the desired level of service for a set of assets. It would then be necessary to determine the level of investment (or allocation of other scarce resources) required to support this level of performance. At least one—and potentially many—iterations are required for an agency to determine a target performance that is not only consistent with its goals and objectives but also attainable given available resources. At each step, it can be helpful to use predicted performance given a certain allocation of resources to help communicate investment trade-offs and guide decision making.

Once an agency sets its strategic targets, it can then set tactical and operational targets. Developing and tracking such targets allows for better assessment of the actions to be performed at different levels of the organization to support strategic targets, and whether the agency is on track to meet its strategic targets – also termed “line-of-sight integration of decision making.”

Key points in setting performance targets to support TAM resource allocation include:

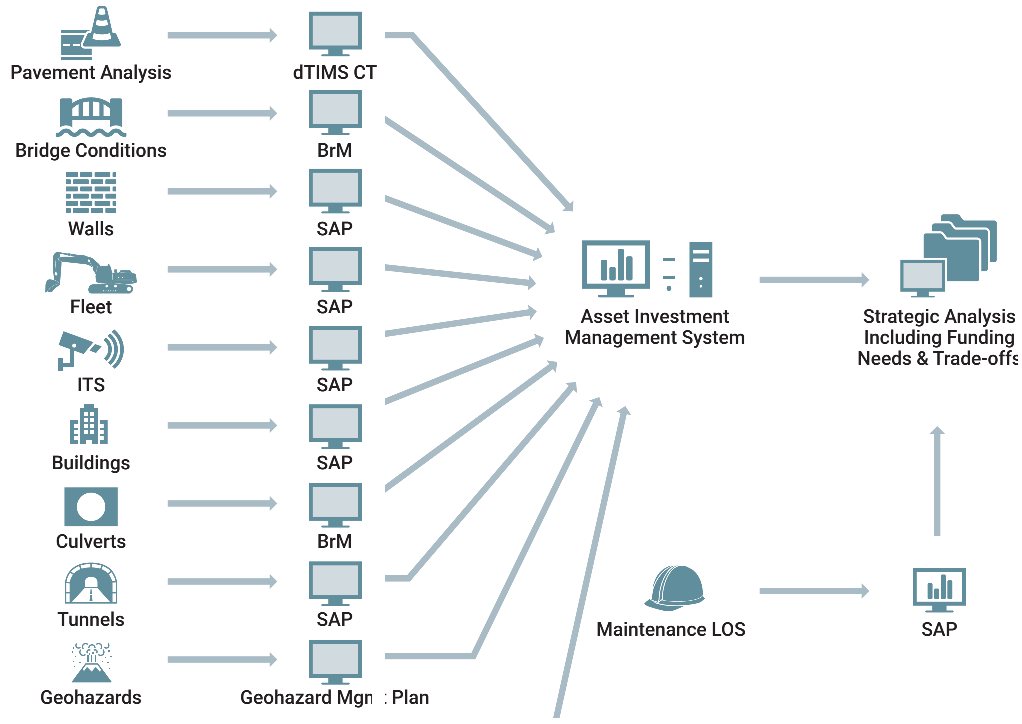
- **Targets should be consistent with agency goals and objectives.** Absent a specific constraint on resources, an organization should allocate resources as required to support its goals and objectives. For investments in existing assets, this should follow the life cycle plans developed as described in Chapter 4. If resources are constrained, it may be necessary to revise the life cycle strategy followed for one or more asset classes to focus investment on specific areas, although this may result in higher costs or worse performance in other areas over time.
- **Use management systems to support target developmen**t. Pavement, bridge, and other asset management systems provide robust tools for summarizing current conditions and predicting future conditions and performance. In setting performance targets, it is important an agency use the analytical capabilities these systems offer in order to develop targets supported by data using a documented, repeatable process. Management systems are useful tools to help the decision-making process, but should support the process, not define it. Establish the allocation process the agency wants, and find tools that help implement it.
- **An agency may have different targets for different subsets of a network.** Particularly with strategic targets set at a network level, it will generally be the case for some subsets of the network or different geographic areas that performance will exceed the overall target, while others will lag behind the target.
- **Factors not considered in management systems can impact performance.** While management systems can help determine realistic targets, a decision maker should note the simplifying assumptions these systems make and thus remain aware of additional factors that may impact performance. For instance, management systems typically assume treatment on an asset can be performed in a single decision period, and the resulting impact on performance is immediately observed. In reality, projects often require multiple years to complete and there may be significant lag between when funds are committed and a resulting change in performance is observed. Factors outside the scope of management systems may also impact performance,

such as diversions for emergency events or variability in condition assessment data and deterioration rates.

Practice Example
Use of Performance Targets to Support Resource Allocation

Colorado DOT

The budget-setting process used by CDOT and described in its 2018 TAMP is an example of a resource allocation process emphasizing use of performance targets to support cross-asset resource allocation. CDOT organizes its asset inventory into 12 different asset classes and the Asset Investment Management System is used to calculate current conditions and predict future performance given a specified budget and other data. The figure below illustrates the asset classes and systems used to support analysis of each asset class as of 2018. The measures used summarize conditions that vary by asset class. For instance, for pavement CDOT forecasts percent of pavement with high, moderate, and low drivability life. For bridges CDOT forecasts percent of bridges in good/fair/poor condition based on the FHWA bridge condition measure. For maintenance and buildings CDOT forecasts a level of service on a letter grade (A to F) scale. On an annual basis CDOT performs a separate analysis for each asset class of existing conditions, and predicted conditions for different budget scenarios. The manager for each asset class then presents a budget request and business case for the asset class in a workshop setting. Workshop participants, including the asset class managers and representatives from each CDOT region, then vote on the allocation of budget by asset class. The allocation serves as a recommendation to CDOT's Transportation Commission, which is charged with adopting CDOT's budget. Separate processes are used in each asset area to prioritize work once the budget is established.



CDOT Asset Classes and Analysis Systems
Source: William Johnson, 2018 FHWA TAM Peer Exchange

Source: CDOT Transportation Asset Management Plan. 2018.
https://www.codot.gov/programs/colorado-transportation-matters/documents/risk-based-transportation-asset-management-plan.pdf

TIP In many ways, resource allocation is the culmination of other TAM processes. These next pages describe how outputs from other processes should inform resource allocation for data driven decision making.

Use of Multi-Objective Decision Analysis for Resource Allocation

Multi-Objective Decision Analysis (MODA) can be used to prioritize specific candidate investments considering multiple, potentially competing objectives. Though this approach is data-intensive, it provides the means for evaluating investments that combine multiple types of assets or investments that help achieve multiple objectives.

In recent years, interest has increased in using MODA to improve approaches for prioritizing investments across asset classes and investment categories. The basic benefit of this approach is that it provides a structure for prioritizing investments outside the scope of any one management system, such as projects combining pavement, bridge and safety improvements. It also provides a means to compare asset management investments with other investments to improve mobility and achieve other objectives outside the scope of a typical asset management system.

This approach is, however, more data intensive and may result in simplification of the asset-specific modeling performed in a pavement or bridge management system. MODA tools and approaches are typically intended for application in analyzing specific candidate projects, and used for prioritizing investments for a single decision period. However, it is possible to adapt a MODA approach for cases where data are sparse or where groups of investments are analyzed rather than specific investments, or where longer decision periods are considered.

NCHRP Report 806: Guide to Cross Asset Resource Allocation and the Impact on Transportation System Performance presents a framework and prototype tool for implementing a MODA-based approach. Additional research through NCHRP Project 08-103 extended the framework and updated the tool. A checklist based on this work is included in this section; it outlines key issues for an agency considering improvements to its resource allocation approach to better account for multiple objectives across asset classes or investment categories.

Practice Example
Cross-Asset Resource Allocation

North Carolina DOT

Highway Scoring - Eligible Criteria with P5.0 Measures

Criteria	Measure	Existing Conditions	Project Benefits (Future Conditions)
Congestion	Volume/Capacity + Volume	✓	
Benefit / Cost	(Travel Time Savings + Safety Benefits) / Cost to NCDOT		✓
Safety / Score	Critical Crash Rate, Density, Severity, Safety Benefits	✓	✓
Economic Competitiveness	% Change in Jobs + % Change in County Economy		✓
Accesibility / Connectivity	County Economic Indicator, Improve Mobility	✓	✓
Freight	Truck Volume, Truck %, Future Interstate Completion	✓	
Multimodal	Multimodal Benefits		✓
Lane Width	Existing Width vs. Standard Width	✓	
Shoulder Width	Existing Width vs. Standard Width	✓	
Pavement Score	Pavement Condition Rating	✓	

Since 2009 NCDOT has used a structured approach to help prioritize capital investments across multiple modes and asset classes. The initial version of the approach implemented in 2009 (Prioritization 1.0) focused on prioritizing mobility and highway modernization projects supported by data on congestion, crashes and pavement condition. North Carolina's Strategic Transportation Investments (STI) Law enacted in 2013 formalized the process and directs NCDOT to select and fund major capital improvement projects using a data-driven prioritization process in combination with local input. The STI Law requires that NCDOT allocate 40% of its available funds for mobility to Statewide Mobility projects that address congestion and bottlenecks, 30% of funds to projects with Regional Impact that improve connectivity within Regions, and 30% of funds to Division Needs projects that address local needs. Different scoring metrics are used for prioritizing investments in each mode (highways, aviation, bicycle-pedestrian, public transportation, ferry and rail) within each of these three funding categories. In Prioritization 5.0, implemented in 2018, highway projects were categorized into 24 different types of improvement types. Highway candidate projects are evaluated through 10 criteria as named in law and defined by a Workgroup of planning partners, including pavement condition, considering a mix of existing conditions and predicted conditions as a result of the proposed project, as illustrated in the figure.

Source: NCDOT. 2019. https://connect.ncdot.gov/projects/planning/MPORPODocuments/P5.0%20Master%20Presentation%20-%20July%202018.pdf

Practice Example
Multi-Objective Allocation Approach

Caltrans

The approach for allocating funding within the Caltrans State Highway Operation and Protection Program (SHOPP) is an example of a "bottom-up" multi-objective, cross-asset resource allocation approach. The SHOPP funds repair, preservation, and safety improvements on the California State Highway System (SHS). The SHS is comprised of approximately 50,000 lane miles and the 2018 SHOPP will implement $17.96 billion in projects over four years. The SHOPP programming cycle results in a four-year program of capital projects that achieve the performance targets specified in the TAMP, consider the fiscal constraints, and address the needs identified in the State Highway System Management Plan.

In an effort to make the process more data-driven, Caltrans piloted a MODA approach to prioritize projects for inclusion in the SHOPP. The agency used the goal areas identified in their Strategic Plan (Safety and Health; Stewardship and Efficiency; Sustainability, Livability, and Economy; System Performance; and Organizational Excellence) and established criteria to evaluate projects across the five goals. In the initial pilot, Caltrans focused on obtaining the technical data necessary to evaluate how well each project progressed towards its goals. The agency is in the process of refining the approach based on the results of the pilot. They revised the goal areas to best account for all the activities included in the project. In addition, they represent each project score through a monetized benefit value, which addresses challenges related to scaling and weighting. With the revised approach, projects are scored based on the annual benefit of performing the project relative to deferring work for one decision period (two years). Benefits predicted using the approach are analogous to monetized benefits predicted using benefit/cost analysis tools and approaches, such as the Cal-B/C tool Caltrans uses to evaluate potential highway improvements. This approach leverages prior work performed to quantify the benefits of a proposed investment, and helps address issues with scaling and weighting different measures of benefit encountered in the initial pilot.

Source: TAM Peer Exchange Presentation. 2018 SHOPP http://www.dot.ca.gov/hq/transprog/SHOPP/2018_shopp/2018-shopp- adopted-by-ctc.pdf
NCHRP 08-103, Preliminary Draft Final Report

How-to

Implementing a Multi-Objective Decision Analysis (MODA) Approach

This checklist provides a list of the steps involved in implementing a MODA approach. Agencies can use this checklist to determine if they have considered all the necessary steps in setting up their approach for prioritizing projects or investments. Note that this checklist is a summary of the materials presented in the final report of NCHRP Project 08-103. This report has additional details on each of the elements described here.

1. Establish the Scope

- **Determine which assets to include.** Specify the asset classes to consider as part of the analysis. Often a cross-asset resource allocation approach will focus initially on pavements and bridges, but may extend to other asset classes as well, such as drainage assets, traffic and safety assets, and facilities.
- **Determine which investments to include.** A cross-resource allocation decision-making process should include investments in existing assets, such as preservation, rehabilitation and replacement or reconstruction actions. The process may include other types of investments, such as improvements in safety or mobility, as well.
- **Determine the investment period.** It is also important to determine the time frame for investments being considered. Often the process is defined to prioritize investments over a single one or two-year decision period, but it may be defined to include investments over multiple periods.
- **Decide how the approach relates to the existing business process.** Every organization has some sort of process for making decisions about it investments in its assets. In this step one must consider the existing process and how an improved cross-asset resource allocation process will be integrated into it. For instance, the process might entail replacing one or more steps in the existing process with a more formal approach to identifying investment needs and prioritizing potential investments.
- **Decide how the results will be used.** One must decide how the results of the process are intended to be used. Will they help establish the level of investments in different assets or types of investments? Or provide an initial set of priorities for decision-makers to review? Or help document the final selection of specific candidate investments through a formalized process?

MODA Implementation

1. Establish the Scope
2. Define Goals and Objectives
3. Select Performance Measures and Evaluation Criteria
4. Assess Data and Analytical Capabilities
5. Prototype the Approach
6. Set Weights on Goals and Objectives
7. Apply the Model
8. Communicate the Results

How-to

Considerations in Implementing a Multi-Objective Allocation Approach

2. Define Goals and Objectives

- **Review existing agency documents describing agency mission.** Review the organization's strategic plan, long-range transportation plan, and other planning document. Typically investment goals are defined in areas such as: mobility; preservation; safety; security; resilience; environment; community; economic development; accessibility; and environmental justice.
- **Define goals.** Determine the goals that will be addressed through the cross-asset investments. A cross-asset resource allocation process is often focused on a subset of the organization's goals, such as improving safety. However, investments in existing assets may yield progress towards achieving other goals as well.
- **Define objectives supporting each goal.** For each goal under consideration, one must determine the objectives supporting it. For instance, if the goal is to preserve existing assets, the specific objectives might be to improve pavement and bridge conditions. Or if the goal is to improve safety, the objective may be to reduce the number of fatal crashes.

3. Select Performance Measures and Evaluation Criteria

- **Select measures supporting each objective.** One must identify specific performance measures that relate to each objective. The measures, once quantified, should demonstrate whether the organization is making progress towards meeting its goals and objectives. The final report for NCHRP Project 08-103 provides examples of measures used for cross-asset resource allocation.
- **Determine how to quantify each measure.** Once measures have been selected one must determine how best to quantify them. Ideally, a measure should be based on quantitative data, such as a measure of asset condition. However, where it is not feasible to obtain quantitative data, it may be necessary to use a qualitative evaluation of the improvement resulting from an investment, such as a five-point scale based on expert judgment.
- **Consider how measures scale based on project size.** It is important to consider how the measures selected will vary with the size of a project. Often, quantitative measures–such as deck area of bridges in good condition, reduced number of crashes, or hours of delay–scale naturally with the size of a project. Where qualitative measures are used, the issue of scaling is particularly important, and it may be necessary to adjust how a measure is defined to account for the scale of a project. If two projects yield the same result in terms of some measure, then most structured approaches will higher prioritize the project that provides the same result at a lower cost.
- **Normalize the measure for comparison between projects.** Once performance measures are defined, they must be normalized to a defined scale. Most structured processes requires normalizing measures on a scale from 0 to 100 percent, where 100 percent is the greatest achievement possible towards a given objective.

How-to

Considerations in Implementing a Multi-Objective Allocation Approach

4. Assess Data and Analytical Capabilities

- **Determine how to measure and predict each measure.** Review available data to determine how to quantify each measure using a combination of existing data and predictive models.
- **Revisit the analysis scope and measures.** Revise the scope of analysis and measures as needed to reflect any issues revealed in existing data. For instance, if needed data are not available and cannot be easily predicted, it may be necessary to revise the process to handle selected types of investments separately.
- **Collect additional data.** Collect any additional data required to support the process. This might include collecting more data on assets that might be improved through a proposed investment, or collecting additional data on past projects to better predict the impact of future investments.

5. Prototype the Approach

- **Collect data for sample projects.** Test the process on a set of sample projects. The test project should be representative of the full set of assets, investment types, and objectives included as part of the process.
- **Calculate project performance.** Walk through the process of predicting performance for test projects using the previously-defined measures.
- **Review and revise the approach.** Review and revise the approach as needed. This may include revisions to the scope of the process, reconsidering goals and objectives, making adjustments to performance measures, and/or changing how measures are scaled and normalized.
- **Document the approach and assumptions.** Carefully document the approach and supporting assumptions to aid in the remaining steps of the process.

6. Set Weights on Goals and Objectives

- **Determine weighting approach.** Decide how the goals and objectives will be weighted. The final report for NCHRP 08-103 describes different options for weighting measures, including using a panel of experts to perform a pairwise comparison of different goals, voting on weights using the Delphi Method, or using Data Envelopment Analysis to establish weights programmatically using a data-driven approach.
- **Use the approach to set weights.** Set weights on each goal and objective. This may require conducting a workshop with a set of experts to perform pairwise comparisons or vote on weights.

How-to

Considerations in Implementing a Multi-Objective Allocation Approach

7. Apply the Model

- **Identify candidate investments.** Use the cross-asset allocation approach to prioritize investments. Potential or candidate investments are identified that will be prioritized as part of the process.
- **Calculate measures for each candidate.** For each candidate investment, calculate the measures that will result from the investment using the established approach.
- **Prioritize candidates.** Follow the previously-established approach to prioritize the candidate investments.
- **Use priorities to support resource allocation.** Use information on priorities to aid the resource allocation process. The process may result in a score for each of a set of candidate projects that is then used by decision makers when deciding which investments to pursue. Or the process may include performing an optimization to determine which investments would maximize performance, subject to budget and other constraints.
- **Update key assumptions and parameters as needed.** Carefully document the approach and supporting assumptions to aid in performing the remaining steps of the process.

8. Communicate the Results

- **Document approach.** Document the results of the cross-asset resource allocation approach, including the priorities on different investments generated using the approach.
- **Document key assumptions and parameters.** Record information on the parameters used in the analysis. This should include documentation on how different objectives were weighed, and the weights that were established.
- **Make the results available to stakeholders.** Share results of the prioritization process with key stakeholders.

Section 5.3

Financial Planning

A TAM financial plan describes the sources of an organization's funds and how funds will be used over time on TAM activities. Resource allocation and TAM financial planning are closely linked activities. TAM financial planning both contributes to the resource allocation process and uses its results.

This section has two parts:

1. **TAM Financial Planning Overview.** This section describes the contents of a TAM financial plan.
2. **Implications for Resource Allocation.** This section describes how a TAM financial plan can inform resource allocation decisions, and how decisions concerning resource allocation are reflected in a financial plan.

TAM Financial Plan

A financial plan describes the sources of an organization's funds and how funds will be used over time. Fundamentally, an organization prepares financial plans because it is good business practice and because doing so is required to comply with various state and federal requirements and accounting standards.

MPOs are required to prepare financial plans as part of LRTP and TIP development. DOTs also have to prepare financial plans for their NHS TAMPs. The federal requirements help guide practice in many agencies. However, there are often additional state-level requirements for financial planning and reporting that may impact the preparation of financial plans.

The financial plan prepared for an MPO LRTP requires system-level estimation of costs and revenue sources with reasonably expected availability to adequately operate and maintain the federal-aid highways included in the plan. LRTPs have a planning horizon of 20 years or more, but beyond the first 10 years of the plan the costs may be specified using aggregate cost ranges. MPOs, transit operators and states are required to work together to develop the financial plan. Requirements for LRTP financial plans are listed in 23 CFR 450.324 (f)(11).

The financial plan for a MPO TIP serves a similar purpose as for an LRTP: to show that funding is reasonably expected to be available for projects within the plan. Funds must be estimated by year for over a period of at least four years. A TIP financial plan does not need to include funding for other activities outside of the projects included, but should include some form of system-level estimation of costs of operating and maintaining federal-aid highways, as well as confirmation that sufficient funds are available for implementing, operating and maintaining the system. As in the case of LRTP financial plans, MPOs, transit operators and states are required to work together to develop the plan. Requirements for TIP financial plans are listed in 23 CFR 450.326 (j).

For SLRTP and STIPs, the elements of a financial plan are similar to those for LRTPs and TIPs, respectively. However, the financial plan for these documents is an optional element. SLRTP requirements are described in 23 CFR 450.216 and STIP requirements are described in 23 CFR 450.218.

Separate requirements specify the contents of a financial plan prepared for a State's NHS TAMP. 23 CFR 515 specifies that a TAMP financial plan is a "long-term plan spanning 10 years or longer, presenting a State DOT's estimates of projected available financial resources and predicted expenditures in major asset categories..."

Regulations further stipulate that the process for preparing a financial plan must include:

- Estimating the cost of expected future work to implement the investment strategies in the TAMP by fiscal year and work type
- Estimating funding levels that are expected to be reasonably available by fiscal year
- Identifying anticipated funding sources
- Estimating the value of the agency's NHS pavement and bridge assets
- Estimating the needed investment on an annual basis to maintain asset value

In addition to preparing financial plans in the

TIP **Risk can be incorporated into resource allocation informally (as general considerations) or more formally (e.g. through the life cycle management process or as a criteria in a multi objective decision making process).**

documents described above, state DOTs and other organizations typically prepare annual financial statements. The U.S. Governmental Accounting Standards Board (GASB) establishes standards for state and local governments to use in following Generally Accepted Accounting Principles (GAAP). These standards describe how governments should perform their accounting and prepare financial statements. A financial statement prepared based on GAAP describes an organization's financial position for a given reporting period, such as a fiscal year, and typically does not include detailed projections of future funding and work. A financial statement prepared to comply with GASB standards and a financial plan prepared to support an LRTP, TIP or TAMP are meant to serve different purposes, but the same underlying concepts inform the development of all these products.

Financial statements and Federally-compliant NHS TAMPs both include calculations of asset value. Reporting asset value in a TAM financial plan helps communicate what assets an organization manages in a common unit applicable to all assets: dollars. Estimates of asset value in a TAM financial plan are typically based on asset replacement cost. The value of an asset may be depreciated on remaining asset life or current asset condition. Where a depreciated asset value is calculated the cost to maintain asset value is equal to annual depreciation. This can provide a useful benchmark for the minimum spending required to maintain an inventory of assets.

The asset value reported in a financial statement is prepared in compliance with GASB requirements, and is often prepared differently than that in a TAMP. For financial statements agencies typically apply straight-line deprecation to historic capital costs to estimate the current book value of their assets. The historic cost of constructing an asset is different from the cost to replace an asset in today's dollars, and the annual depreciation calculated using this approach is different from the cost of actually maintaining asset condition. GASB requirements allow for addressing this issue using a "modified approach" for calculating asset value. This alternative approach involves calculating a cost to maintain assets using an organization's management systems in lieu of calculating straight-line depreciation. Where this approach is used it provides a calculation of asset value that can be used in both a TAM financial plan and an organization's GASB-compliant financial statement.

Implications for Resource Allocation

In determining how to allocate financial resources, a decision-maker needs information on available funds. The output of the resource allocation process is an allocation of funds or other resources needed for the financial plan. Thus, financial planning both informs the resource allocation process and uses its results.

Development of a financial plan is separate from, but closely related to, the resource allocation process. Thus, there must be a high level of coordination between financial planning and resource allocation, particularly with respect to TIP and TAMP financial plans.

Although different financial plans are required for different applications, for practical purposes an organization should use consistent assumptions in developing its financial and strategic plans to the fullest extent possible, including the plans described above and other related documents.

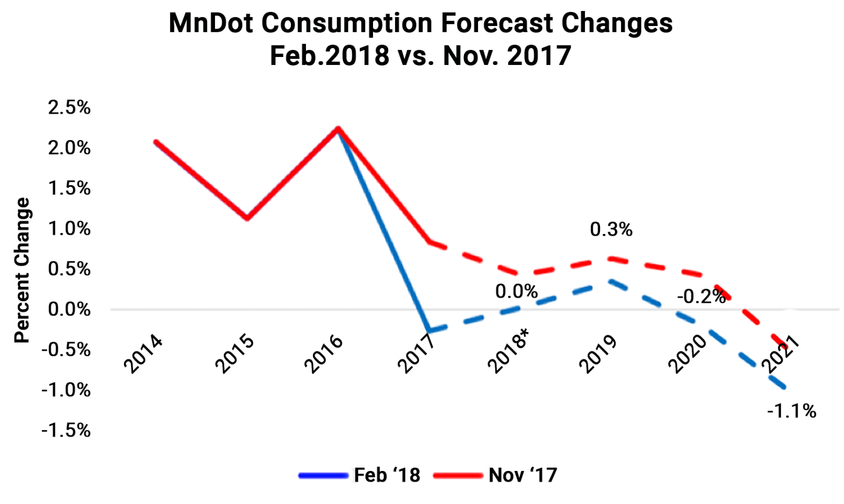
Areas where integrated approaches and assumptions between different planning documents are most beneficial are:

- **Revenue projections.** Ideally, a single office or group should take responsibility for projecting future revenues incorporating the organizations best estimates of revenue sources, demographic trends and other factors.
- **Inflation assumptions.** To predict how much it will cost to perform work in current dollars it is necessary to apply an appropriate inflation assumption. Predicting future inflation is challenging and results of the resource allocation process may be highly sensitive to the assumed inflation rate. Thus, it is important for an organization to make a consistent set of assumptions concerning inflation in its different financial plans. Often, the same unit responsible for revenue projections also predicts future inflation.

Practice Example
Revenue Projection

Minnesota DOT

MnDOT forecasts future funding in its annual Transportation Funds Forecast. This document projects funding by source for a four-year period. The report includes the funding projection, as well as additional details supporting the projections. For instance, it details trends in key parameters that impact funding, such as fuel consumption and vehicle sales. For these and other parameters the report shows historic trends, prior projections, and revised projection. The graph below, reproduced from the 2018 report, shows data for historic and predicted fuel consumption. The report also documents reasons for any changes in the projections, and risks that may impact future revenue. MnDOT uses its revenue projections to support development of the STIP, as well as to inform the funding projections in other reports, such as the TAMP and LRTP.



Source: MnDOT Transportation Fund Forecast. 2018.
http://www.dot.state.mn.us/funding/documents/Transportation%20Forecast%20Feb%202018.pdf

- **Operating and maintenance costs (O&M).** Costs of operating and maintaining existing assets may be components of the different federally-required plans, but they typically are not a focal point of the planned use of capital funds. From an asset management perspective, it is important to accurately predict these costs and include them as part of any financial plan.

While integrating approaches is highly desirable, the varying scopes and requirements for different financial plans and statements may lead to different results even when approaches are integrated. Financial planners should still carefully document and communicate any areas where different financial plans and statements appear to diverge.

Such instances can result from:

- **Timing of plan preparation.** A transportation agency's financial situation may change from year-to-year or even day-to-day. A financial plan captures an agency's best estimates at a given point in time, and it is not uncommon that the financial assumptions made for a given plan will be different when revisited for another plan at a later time.
- **Different planning horizons.** Long-range plans, TIPS and TAMPs all have different planning horizons. The length of the planning horizon can impact how numbers are presented in a plan and how they are communicated. For instance, the average annual O&M cost for the Federal-aid system, stated in current dollars, will be different over a 20-year period than over a 10- or 4- year period due to the effects of inflation and changing system conditions.
- **Different contexts.** Although using consistent assumptions and approaches between different financial plans and statements is desirable, in some cases the varying contexts and requirements demand the use of different approaches. An example of this issue is in asset valuation described in the previous section.

Practice Example
Asset Valuation

City of Ottawa

The Province of Ontario was one of the first jurisdictions in Canada to pass legislation that required all municipalities within the province to prepare an asset management plan for all core municipal infrastructure. Municipalities have since been undertaking similar planning methods to all municipal infrastructure. Initial regulations required plans to have specific components including the Current State of the Infrastructure (a summary of replacement value, current condition, the rate of depreciation and resulting residual value of the portfolio) as well as other components (Levels of Service, Asset Management Strategy, Financing Strategy and Improvement Plan). The State of Infrastructure reporting is a useful method to provide a snapshot of the current status of infrastructure and its ability to continue to deliver services. The City of Ottawa has been a leader in developing a comprehensive asset management program and making infrastructure investments based on a systematic approach. For example, State of the Infrastructure reporting is conducted for all asset types, and summarized in periodic council reporting.

Service	2017 Status		2012 Status	
	Asset Replacement Value	Overall Condition Rating	Asset Replacement Value	Overall Condition Rating
Water	$ 7,465 M	Good-Fair	$ 6,638 M	Good
Wastewater	$ 7,193 M	Fair-Good	$ 5,678 M	Good-Fair
Stormwater	$ 6,296 M	Good-Fair	$ 4,670 M	Good-Fair
Solid Waste	$ 59 M	Good-VG		
Transit	$ 1,980 M	Fair-Good	$ 1,951 M	Good-Fair
Transportation	$ 12,612 M	Fair	$ 11,076 M	Fair
Parks, Rec and Culture	$ 2,232 M	Fair	$ 1,970 M	Fair
Libraries	$ 126 M	Good	$ 94 M	Good
Social Services	$ 3,032 M	Good-Fair	$ 176 M	Good-Fair
Fire	$ 291 M	Fair		
Paramedic	$ 44 M	Good	$ 313 M	Good-Fair
Bylaw	$ 13 M	Fair		
Police	$ 148 M	Fair		
Corporate Services	$ 338 M	Fair-Poor	$ 257 M	Fair
Information Technology	$ 123 M	Fair		
Overall Summary	$ 41,953 M	Fair-Good	$ 32,823 M	Fair-Good

Source: City of Ottowa Comprehensive Asset Management. 2019. https://ottawa.ca/en/city-hall/accountability-and-transparency/corporate-planning-and-performance-management-0

Checklist

Preparing a TAM Financial Plan

This checklist summarizes the basic steps involved in preparing a TAM financial plan. Note this guidance is based on NCHRP Report 898, and this resource has additional details on each of the steps described here.

☐ **Identify and Document Sources and Uses**

- Determine the scope of the TAM program
- Establish sources of funding
- Establish funding uses
- Structure the list of sources and uses
- Validate the list
- Document constraints on uses of funding
- Document assumptions concerning the allocation of fixed costs

☐ **Forecast Revenues and Expenditures**

- Establish roles and responsibilities for revenue forecasting
- Review prior revenue forecasts
- Forecast revenues
- Forecast non-asset management uses
- Determine available funding for asset management
- Document key assumptions

☐ **Develop Investment Strategies and Scenarios**

- Define investment scenarios
- Identify current and planned projects
- Use management systems to predict future conditions
- Perform initial budget allocation
- Identify candidate projects
- Select projects
- Revise prediction of future conditions
- Finalize funding levels by use
- Perform gap assessment
- Document assumptions and investment strategies

Checklist

Preparing a TAM Financial Plan

☐ Calculate Asset Value

- Obtain the value calculate for financial statements
- Calculate depreciated replacement cost
- Compare alternative methods for valuation
- Document the calculation using the preferred method
- Incorporate asset value into the financial plan

TIP Although closely linked, financial planning should not be confused with resource allocation.

Section 5.4

Work Planning and Delivery

Investments are conceived and delivered in many different ways. The different models used for work planning and delivery have an impact on the resource allocation approach.

This section has two parts:

1. **TAM Work Planning and Delivery.** This section describes different approaches to planning and delivering work, including maintenance work and capital projects.
2. **Implications for Resource Allocation.** This section describes how the selection of a delivery approach may impact the resource allocation process.

TAM Work Planning and Delivery

The approach used to deliver work can have a major impact on what investments an organization makes, the resources required to perform work, and work timing. Transportation agencies have many options for performing work, including using internal forces to perform work, and/or using a variety of different contracting approaches.

Typically, U.S. transportation agencies perform some or most of their maintenance work internally, and contract out a large portion – if not all – of their capital projects. The line between the types work performed as maintenance and capital projects varies by organization and is often blurred. Agencies can often use maintenance forces in a flexible manner to perform a wide variety of activities, including preservation activities on pavements, bridges and other assets. However, in the near term, an organization's maintenance resources – staff and equipment, in particular – are fixed. Consequently, the asset owner is challenged to optimize use of these resources to meet immediate needs, such as winter maintenance and incident response, while performing additional work to improve asset conditions wherever possible.

The ability to contract out maintenance work, such as through Indefinite Delivery/Indefinite Quantity (IDIQ) contracts, provides an agency with flexibility in meeting near-term needs. Other approaches for contracting out maintenance work include use of portfolio or program management contracts in which certain operations and maintenance responsibilities for some group of assets is delegated to a contractor over a specified period of time. Section 4.3.3 provides additional details on considerations involved in outsourcing asset maintenance.

Regarding contracting approaches for capital projects, in the U.S., most transportation agencies rely on Design-Bid-Build (DBB) model for delivering their capital programs. With this approach, the project owner designs a project (or contracts for a private sector firm to prepare a design) and solicits bids for project construction following completion of the design. This provides the project owner with control over the process, but can be time consuming and can result in cases where bids for project construction exceed the expected cost developed during design. In recent years, many transportation agencies in the U.S. and abroad have explored improved approaches to work planning and delivery to accelerate completion of needed work, leverage alternative financing approaches and transfer program and project risk.

All of these approaches are intended to reduce the time from initial conception of a project to its completion, and in many cases transfer risks associated with project completion from the public sector to the private sector. As these examples help illustrate, major trends in this area include:

- Group work together by geographic location or type of work to develop fewer, larger, and more easily contracted projects
- Use Design-Build (DB), Design-Build-Finance-Operate-Maintain (DBFOM) and other contracting strategies, wherein a single contract is awarded to design and complete a project, as opposed to separate contracts for design and construction
- Encourage development of Alternative Technical Concepts (ATCs), wherein a contractor proposes an alternative approach

to meeting a contract requirement in the bidding phase

- Select contractors earlier in program/project development through use of Construction Manager-General Contractor (CM-GC) arrangements, where a contractor is selected as Construction Manager while design is still underway
- Use IDIQ contracts and other flexible contracts to provide a more efficient mechanism for performing smaller projects
- Incorporate performance-based specifications, time-based incentives and other specifications in contracts to improve project outcomes
- Outsource operations and maintenance of an asset using program or portfolio management contracts.

Both in the U.S. and abroad there are many examples of public agencies making extensive use of alternative contracting strategies, such as Public-Private Partnerships (P3s) and performance-based contracts to speed project delivery and transfer risk.

While alternate strategies for work planning and delivery hold great promise, all of the approaches described here have advantages and disadvantages and carry their own risks. Use of alternative approaches can save taxpayers money and provide improvements more quickly than a traditional model. Success stories typically result from improving the efficiency of the process and incentivizing the use of better technology and methods, but there are also many cautionary examples in which these strategies have failed to achieve cost savings, time savings or risk transfers as desired. Asset owners should consult the separate body of research in this area (referenced at the end of this section) when exploring the use of alternative approaches and carefully weigh the expected return, advantages and disadvantages of whatever delivery approaches they consider.

Implications for Resource Allocation

The different work delivery approaches that are available should be considered both at the outset of the resource allocation process, and as part of finalizing the resource allocation plan. Frequently it is necessary to consider multiple allocation scenarios using different delivery approaches.

The availability of alternative approaches for work delivery creates opportunities for organizations to improve asset conditions and address other needs in a more efficient manner, thereby performing needed work sooner, at a lower overall cost and/or with less risk to the organization. It is important to consider different work delivery strategies both early in the resource allocation process (as part of Step 2 – Determine Constraints) and at the end of the process (in Step 7 – Finalize Allocation and Plans).

Considering alternative delivery approaches early on as investment needs are identified helps identify options and determine approaches that an organization can use to achieve the best results. For instance, in determining how to allocate resources for asset maintenance an organization may wish to explore the potential for outsourcing additional maintenance work if there are specific constraints on staff or materials that could be relaxed using an alternative delivery approach. To properly assess the alternatives it may be necessary to define multiple scenarios, such as a scenario in which a "business as usual" approach is used for delivery, and a second scenario in which increased flexibility is assumed regarding use of different delivery methods.

Once an initial allocation of resources has been made, it is important to review options for delivery to revisit prior assumptions and identify opportunity to lower costs and improve outcomes. For instance, once overall budget levels have been established by asset and/or work type in a financial plan, an organization may need to revisit delivery options when scoping specific maintenance activities or capital projects.

The practice examples describe improved delivery approaches used in the U.S. and abroad, and discuss their impacts on resource allocation.

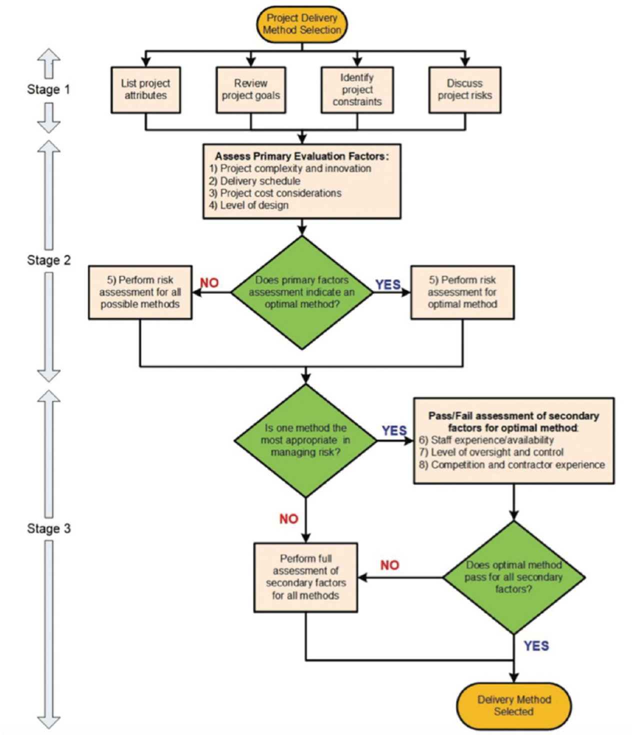
The Work Planning and Delivery checklist lists factors to consider during the resource allocation process for maintenance and capital projects to leverage opportunities for improved work planning and delivery.

Practice Example
Project Delivery Selection

Colorado DOT

In 2011 CDOT's Innovative Contracting Advisory Committee (ICAC) began work to develop a structured approach for selecting the best delivery mechanism for a given transportation project. Through a set of workshops ICAC identified different factors that the agency should consider in selecting a delivery approach, including five primary factors (project complexity and innovation, delivery schedule, cost considerations, level of design, and risk assessment) and three secondary factors (staff experience and availability, level of oversight and control, and competition and contractor experience). ICAC then defined a three-stage approach for making the delivery decision. In Stage 1 CDOT identifies project goals, constraints and attributes. In Stage 2 CDOT assesses the primary factors, and in Stage 3 assesses the additional secondary factors. The approach is illustrated in the figure. As of 2018 CDOT has used the approach to assess 25 different projects, resulting in the selection of a mix of projects using DBB, DB and GM-GC.

Source: TR News 316
http://onlinepubs.trb.org/onlinepubs/trnews/trnews316.pdf



Practice Example • Work Planning and Delivery

Western Australia

Main Roads Western Australia (MRWA) is responsible for Western Australia's highway and main road network. MRWA represents one of the largest geographically spread road agencies in the world, covering an area of 1.55 million square miles. The agency is responsible for approximately 11,200 miles of Western Australia's 93,000 mile network (12%) which carries 60% of the state's traffic. MRWA has been a leader in trialing alternative procurement models to manage operations, maintenance and renewal on their road network.

Beginning in the mid 1990's MRWA underwent major restructuring, and at that time shifted from performing highway asset management and maintenance activities using internal forces to outsourcing these activities through a set of 10-year contracts. As initial outsourced contracts came to an end, MRWA took the opportunity to capture lessons learned over the previous years and researched other national and international methods for delivery of maintenance activities. These investigations concluded that MRWA should pursue a new procurement strategy based on the use of Integrated Service Agreements (ISA). An ISA is a contracting arrangement in which the private sector and agency staff work together to deliver, in an integrated manner, a range of services including Operational Asset Management, Road Maintenance, Improvement Delivery and Network Operations. In essence the ISAs "in source" private sector partners to help deliver the range of integrated services that are core to the MRWA business. To do this the ISAs incorporate a performance specified outcome-based approach. The agreements integrated a number of services that were being delivered by a range of different methods and enabled MRWA to regain much more control and influence on when and how the services are delivered, particularly in regard to asset management decisions for maintenance. The shift to this contracting model was driven by:

- The need to rebuild capability and capacity within Main Roads and thereby assist Main Roads to remain an informed purchaser of asset management services. This was achieved by forming close, collaborative working relationships with industry where the best people and systems from each organization are used to deliver "needs based" asset management and "best for network" outcomes;
- The understanding gained from past models that risk needs to be appropriately allocated to the party best able to manage the risk; and the need for flexibility in the model to adapt to changes in network needs and broader Governance issues.

Post-ICA contract renewals further transitioned contract models to advance several agency objectives. These goals included centralizing strategic asset management work, retaining agency core capabilities, demonstrating value for money, continuous improvement and fit for purposes reporting framework and target setting. Recent contracts build in ICA learnings, and are a reflection of changing market factors and enhancing corporate capabilities.

Source: https://audit.wa.gov.au/reports-and-publications/reports/maintaining-state-road-network-follow-audit/appendix-3-integrated-service-arrangements/

Checklist
Work Planning and Delivery

This checklist provides the factors agencies should consider during the resource allocation process to leverage opportunities for improved work planning and delivery. From project-level and agency-level issues, to public policy and life cycle issues, these factors are key to improving work planning and delivery. As a result, agencies may be able to make more efficient and effective resource allocation decisions.

- [ ] **Project-Level Issues**
  - Project Size
  - Cost
  - Schedule
  - Risk Management
  - Risk Allocation
  - Requirements for Sustainable Design Criteria
- [ ] **Agency-Level Issues**
  - Agency Experience
  - Staffing Required
  - Staff Capability
  - Agency Goals and Objectives
  - Agency Control of Project
  - Third-Party Agreements
- [ ] **Public Policy/Regulatory Issues**
  - Competition
  - DBE Impacts
  - Labor Unions
  - Federal/State/Local Laws
  - Federal/State Regulations
  - Stakeholder/Community Input
- [ ] **Life Cycle Issues**
  - Life cycle Costs
  - Maintainability
  - Sustainable Design Goals
  - Sustainable Construction Goals
- [ ] **Other Issues**
  - Construction Claims
  - Potential for Adversarial Relationships

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
Resource Allocation and Prioritization	Emerging	• The goals of infrastructure investment and management are clearly defined. • The long-term investment requirements are understood for all asset classes in the existing portfolio and is based on at least a 20-year horizon to capture near term investment needs and is based on known intervention and replacement costs. • Investment prioritization is directly linked to goals for the agency. • A systematic, repeatable approach is used to allocate resources for high value assets in some departments who are managing infrastructure. • Alternative delivery options considered where problematic issues are encountered.
	Strengthening	• The goals of infrastructure investment and management are clearly defined. • The long-term investment requirements are understood for all asset classes in the existing portfolio, and is based on at least a 20 year horizon, as appropriate to capture all known large interventions for high value assets, and is based on known intervention and replacement costs. • Investment prioritization is directly linked to goals and performance measures are qualitatively are evaluated in the prioritization process. • A systematic, repeatable approach is used to allocate resources, and the process is well understood by key decision-makers in the agency. • Resource allocation methods are trending to become consistent across the agency in the near term. • Alternative delivery options are periodically evaluated in some departments to consider alternative use of resources for service delivery.
	Advanced	• The goals of infrastructure investment and management are clearly defined. • The long-term investment requirements are understood for all asset classes in the existing portfolio, and is based a sufficient horizon to capture the expected service life for all owned assets, and is based on known intervention and replacement costs. • Investment prioritization is directly linked to goals, performance measures and evaluated against the constraints that may exist for the agency. • A systematic, repeatable approach is used to allocate resources, and the process is well understood and employed across the agency by all departments managing infrastructure. • Resource allocation methods are consistent across the agency and supports cross-asset resource allocation methods, where appropriate. • Alternative service delivery options are periodically evaluated systematically to ensure the best use resources for service delivery.
Cross Asset Resource Allocation	Emerging	• Basic decision support tools are embedded across the organization and used to qualitatively inform decision-making for funding allocation between asset classes.
	Strengthening	• Multi-objective allocation approaches are being considered or trialed to allocate funding across asset classes to balance risk, service delivery and investment. • Service levels and associated performance measures are evaluated and considered for allocation decisions • Decision support tools including computerized systems are being procured or implemented to inform decision-making for funding allocation in the future near term.
	Advanced	• Appropriate multi-objective allocation approaches are established in the agency and employed to allocate funding across asset classes to balance risk, service delivery and investment. • Service levels and associated performance measures are evaluated and linked directly with allocation decisions • Decision support tools including computerized systems are embedded across the organization, and used to inform decision-making for funding allocation.

References

Risk

Enterprise Risk Management Guide. AASHTO. Guide discusses the range of risks a transportation agency faces and details how to establish an enterprise risk management program.
Year: 2016

Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs. NCHRP Report 658, TRB. Summarizes the risk management process and describes how to apply the process to reducing risks of project cost overruns.
Year: 2016

ISO Standard 31000. International Standard Organization. Describes the principles, framework and process for risk management. This resource describes a generic process that can be applied across different industries and applications.
Year: 2018

Uses of Risk Management and Data Management to Support Target-Setting for Performance-Based Resource Allocation by Transportation Agencies. NCHRP Report 706, TRB. Provides several cases studies illustrating how consideration of risk can be incorporated into resource allocation.
Year: 2016

Shaping the Next One Hundred Years: New Methods for Quantitative Long-Term Policy Analysis. RAND Corporation, (Lempert, Robert J., Steven W. Popper, and Steven C. Bankes). Provides an overview of approaches for using scenario analysis and RDM to support investment decision-making. (Lempert, Robert J., Steven W. Popper, and Steven C. Bankes, Shaping the Next One Hundred Years: New Methods for Quantitative Long-Term Policy Analysis, Santa Monica, Calif.: RAND Corporation, MR- 1626-RPC, 2003). This is good starting point for information on advanced approaches for formal assessment of risks in areas with deep uncertainty.
Year: 2003

Performance Targeting

Balanced Scorecard. Kaplan and Norton. Is an overall framework for performance management applicable across many industries and applications.
Year: 1996

Best Practices in Performance Measurement for Highway Maintenance And Preservation. NCHRP Project 20-68A, Scan 10-03, TRB.
Year: 2012

FHWA TPM Toolbox. FHWA. Is a key resource for applying performance management concepts to transportation. The Toolbox is an online resource that includes a guidebook, assessment tool, and additional resources. The Guidebook describes the performance management process, including target setting, and supporting components for TPM.
Year: 2019

Performance Based Planning and Programming Guidebook. FHWA. This guidebook describes agencies' performing performance-based planning and programming roles, and describes processes of identifying trends in performance and setting targets.
Year: 2013

Performance Measures and Targets for Asset Management. NCHRP Report 551, TRB. includes a report on different measures used for TAM and a guide for selecting performance measures and setting targets.
Year: 2005

Target Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies. NCHRP Report 666, TRB. Provides guidance on setting performance targets and examples of approaches used in a number of agencies.
Year: 2010

Financial Planning

Financial Planning and Fiscal Constraint for Transportation Plans and Programs Questions & Answers. FHWA. Provides guidance on development of TIP and LRTP financial plan.
Year: 2019
Link: https://www.fhwa.dot.gov/planning/guid-finconstr_qa.cfm

Forecasting Transportation Revenue Sources: Survey of State Practices – A Synthesis of Highway Practice. NCHRP Synthesis 479, TRB. Summarizes the state of the practice in the transportation community for projecting revenue.
Year: 2016

Guide for Financial Planning and Management in Support of Transportation Asset Management. NCHRP Report 898, TRB. Details how to prepare a TAM financial plan for inclusion in an agency's NHS TAMP and/ or other applications.
Year: 2018

References

NHI Course 136002. NHI. provides instruction on TAM financial plans. Note this course includes a web-based component that can be accessed without taking the instructor- led course.
Year: 2019

Financial Planning for Transportation Asset Management. Proctor and Varma. This is a series of six reports on the topic of TAM financial planning prepared for FHWA.
Year: 2015

Work Planning and Delivery

A Guidebook for the Evaluation of Project Delivery Methods. TCRP Report 131, TRB. Guide describes different project delivery options available to transit agencies and presents alternative decision approaches for deter- mining which delivery approach to select for a given project.
Year: 2016

Accelerating Transportation Project and Program Delivery: Conception to Completion. NCHRP Report 662, TRB. Reviews different program/project delivery approaches and presents a set of case studies demonstrating accelerated completion of programs and projects.
Year: 2016

Alternative Technical Concepts for Contract Delivery Methods. NCHRP Synthesis 455, TRB. Describes uses of ATCs in contractingm.
Year: 2018

Construction Manager- at-Risk Project Delivery for Highway Programs. NCHRP Synthesis 402, TRB. reviews the use of CM-GC contracts.
Year: 2010

Guide for Design Management on Design-Build and Construction Manager/General Contractor Projects. NCHRP Report 787, TRB. Describes alternative contracting approaches further, their advantages and disadvantages, and case studies in use of these methods.
Year: 2016

A Guidebook for Implementing Alternative Technical Concepts into Project Delivery Methods. NCHRP Project 08-112, TRB. A guide for using ATCs to improve project delivery.
Year: 2019 - Not published yet

FHWA P3 website. FHWA. The website has additional information and resources on P3s and related approaches.
Year: n/a

Section 6.1
Monitoring Performance Measures

Section 6.2
Monitoring the State of Assets

Section 6.3
Monitoring Funding and Resource Allocation Methods

Section 6.4
Monitoring Asset Work and Costs

Section 6.5
Monitoring Risks and TAM Processes

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

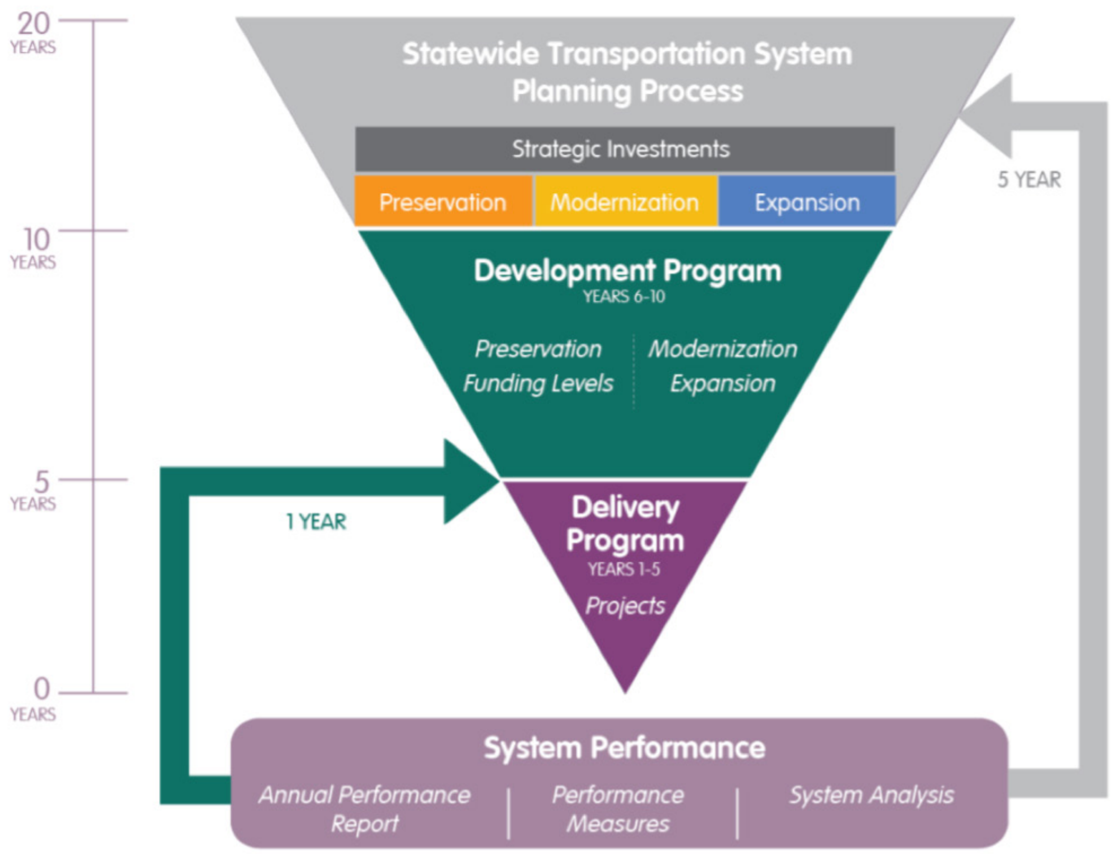
Aligning Investments With Strategic Objectives

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

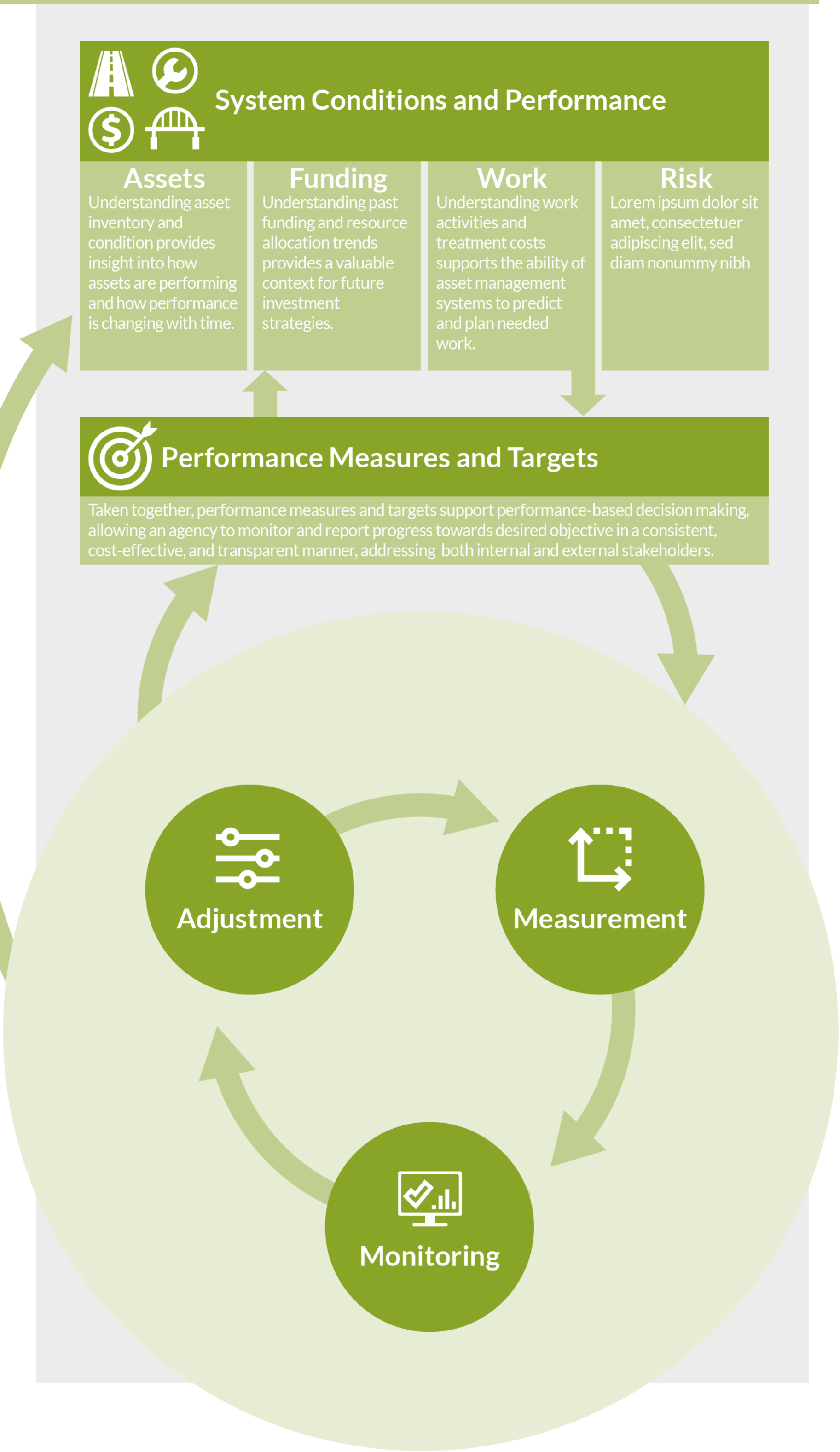
Source: ADOT. 2014. Linking the Long-Range Plan and Construction Program P2P Link Methodologies & Implementation Plan. https://azdot.gov/sites/default/files/2019/08/p2p-methodologies-implementation.pdf

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.

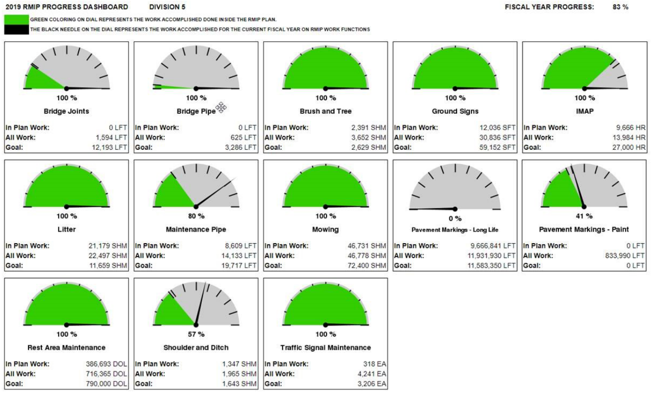
Output-based measures, on the other hand, track the resources used to achieve the outcome, such as the number of hours of labor used or the number of light-bulbs changed in a month. While the data is important information for managing resources, it does not necessarily drive outcomes that would matter 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

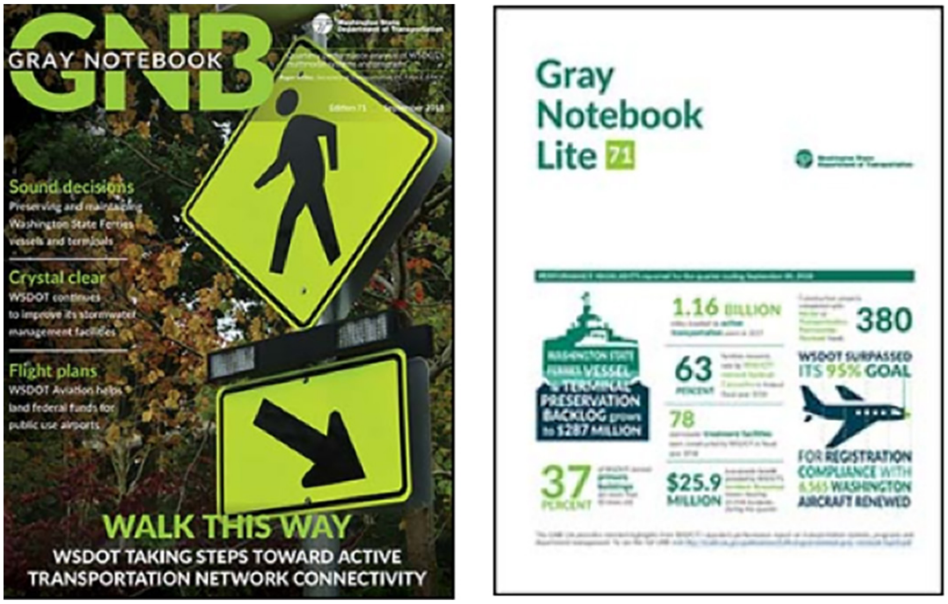
Targeted and Actual Performance Results Used to Set Maintenance Priorities

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.



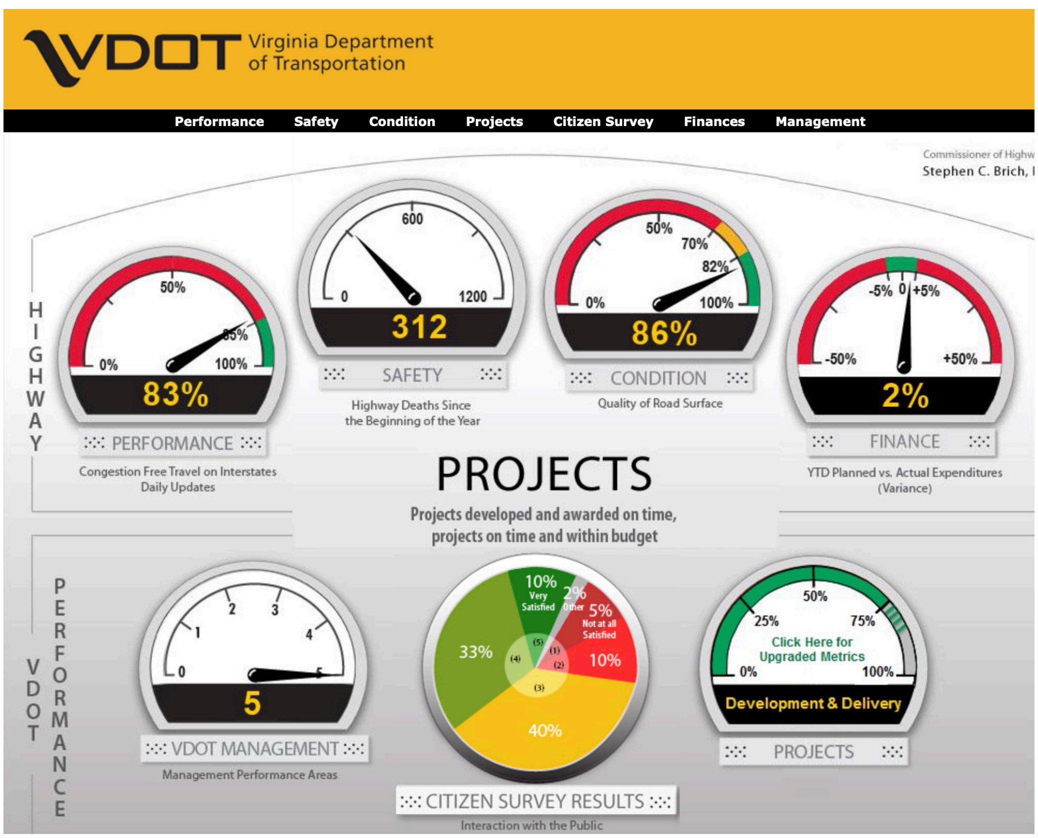
The Gray Notebook and Gray Notebook Lite

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 time-frame for achieving the target.

Benchmarking

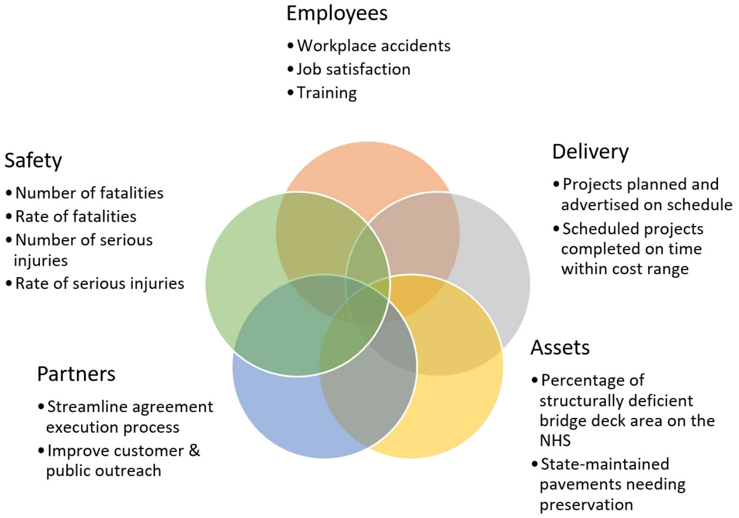
In simple terms, benchmarking is a process of comparing performance and practice among similar organizations as part of an agency's continuous improvement activities. Benchmarking provides an opportunity to learn about approaches used by high-performing organizations to uncover noteworthy practices, 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.

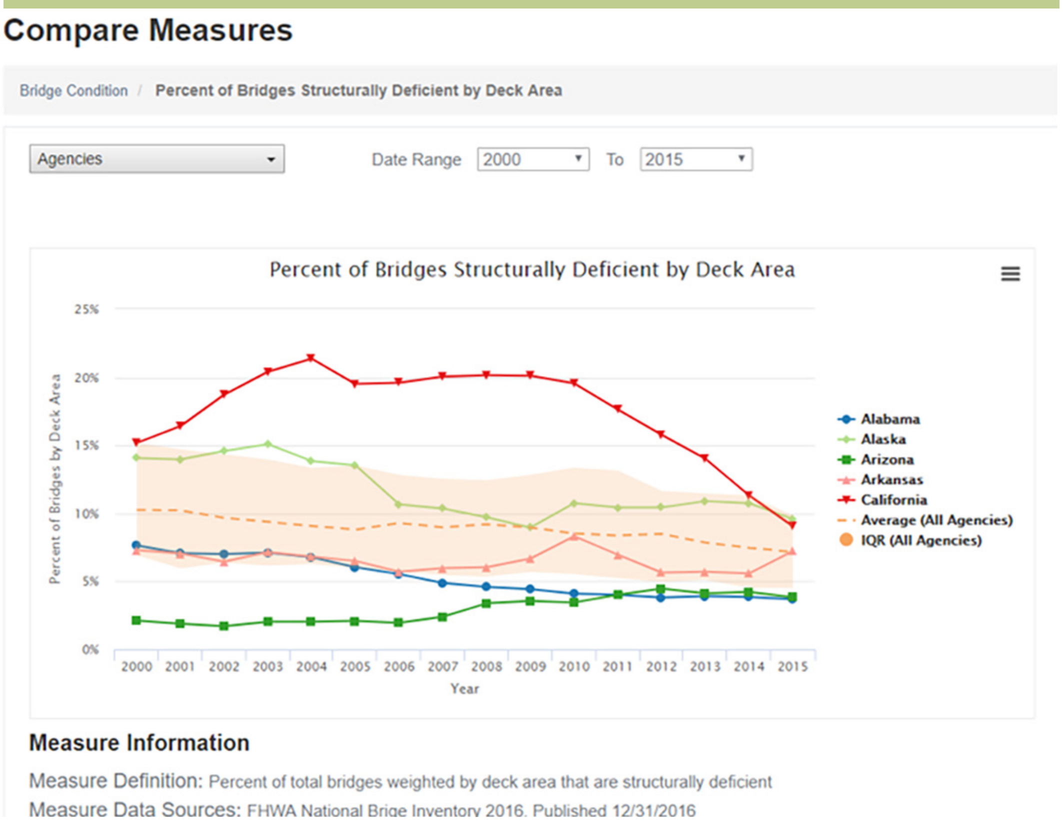
As mentioned in Chapter 1, AASHTO has developed a comparative benchmarking tool for enabling state DOTs to compare performance outcomes and practices with peer agencies as part of their continuous improvement activities (http://benchmarking.tpm-portal.com/). This includes a peer selection tool, so agencies 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

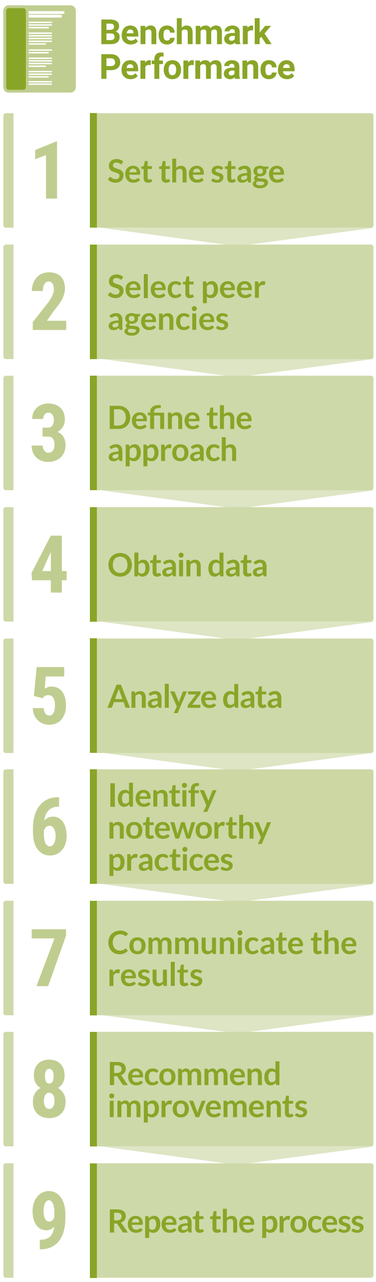
Share the findings with agency leadership, impacted staff, and/or other stakeholders.

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.

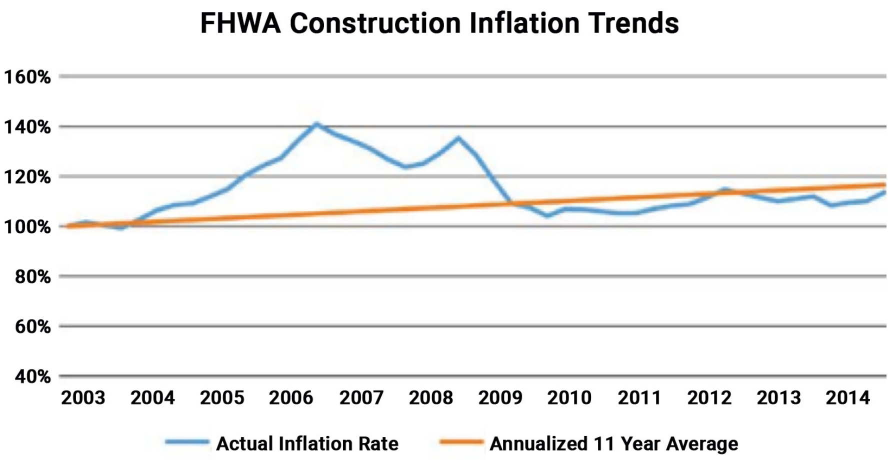
Overcoming Challenges Associated With Trend Analysis

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

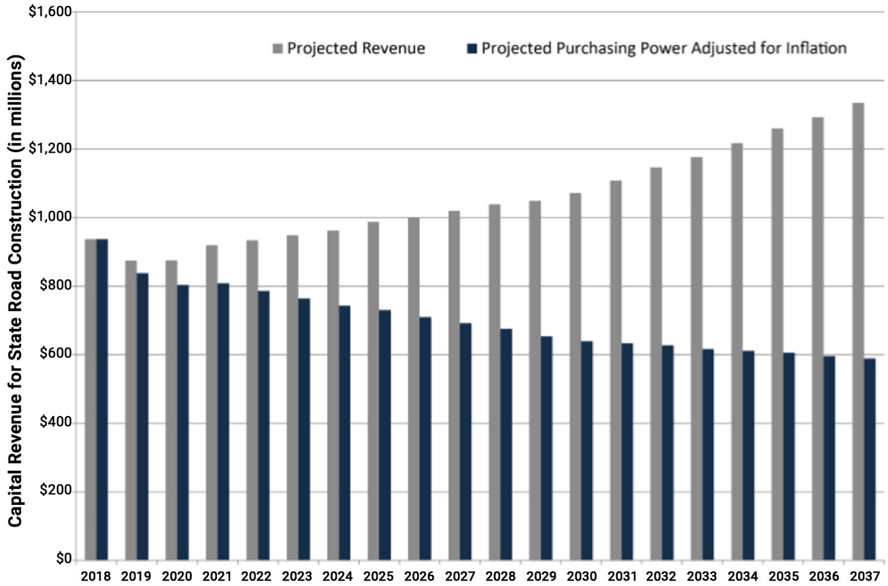
The availability of historical trends is integral for making future projections as part of the planning and programming process. As shown by the examples included in this section, agencies have used trend data creatively to make program adjustments and more effectively align planned investments with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

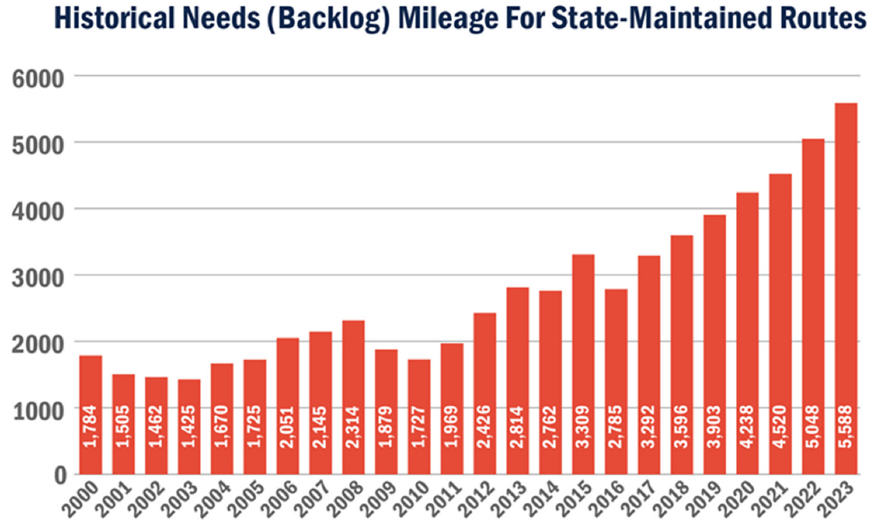


Anticipated construction revenue by year including adjustments for inflation.
Source: Minnesota DOT. *20-Year State Highway Investment Plan 2018-2037.*

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.



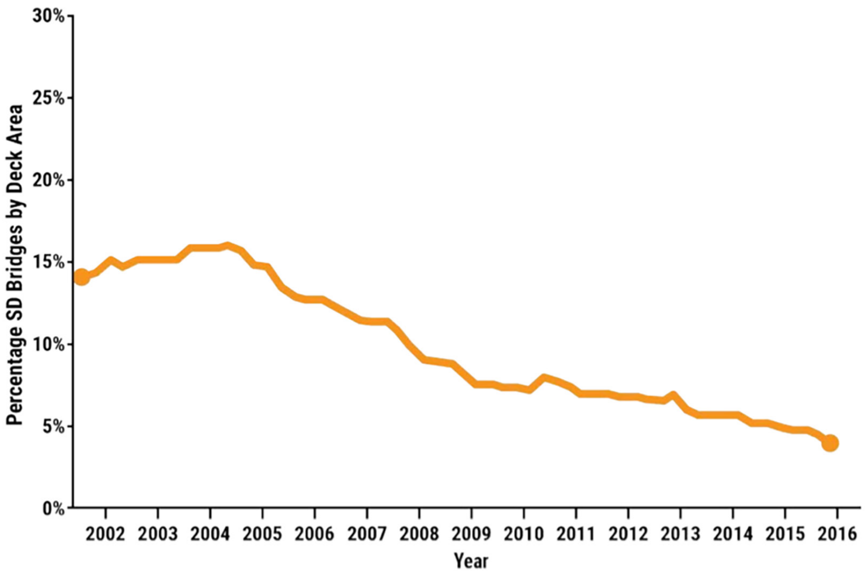
Historical pavement backlog trend.
Source: Illinois DOT Transportation Asset Management Plan. 2018.

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.



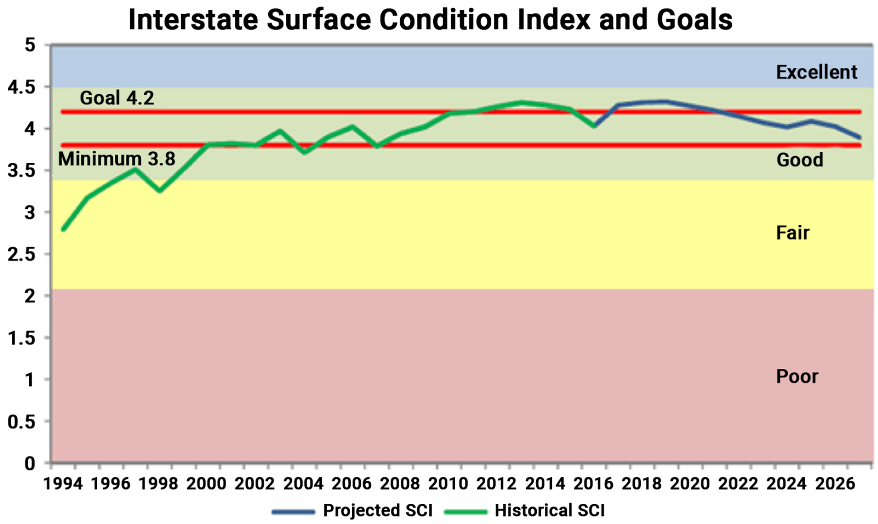
Trend showing the decrease in structurally deficient bridge deck area resulting from targeted investments.
Source: New Mexico DOT Transportation Asset Management Plan. 2018

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.

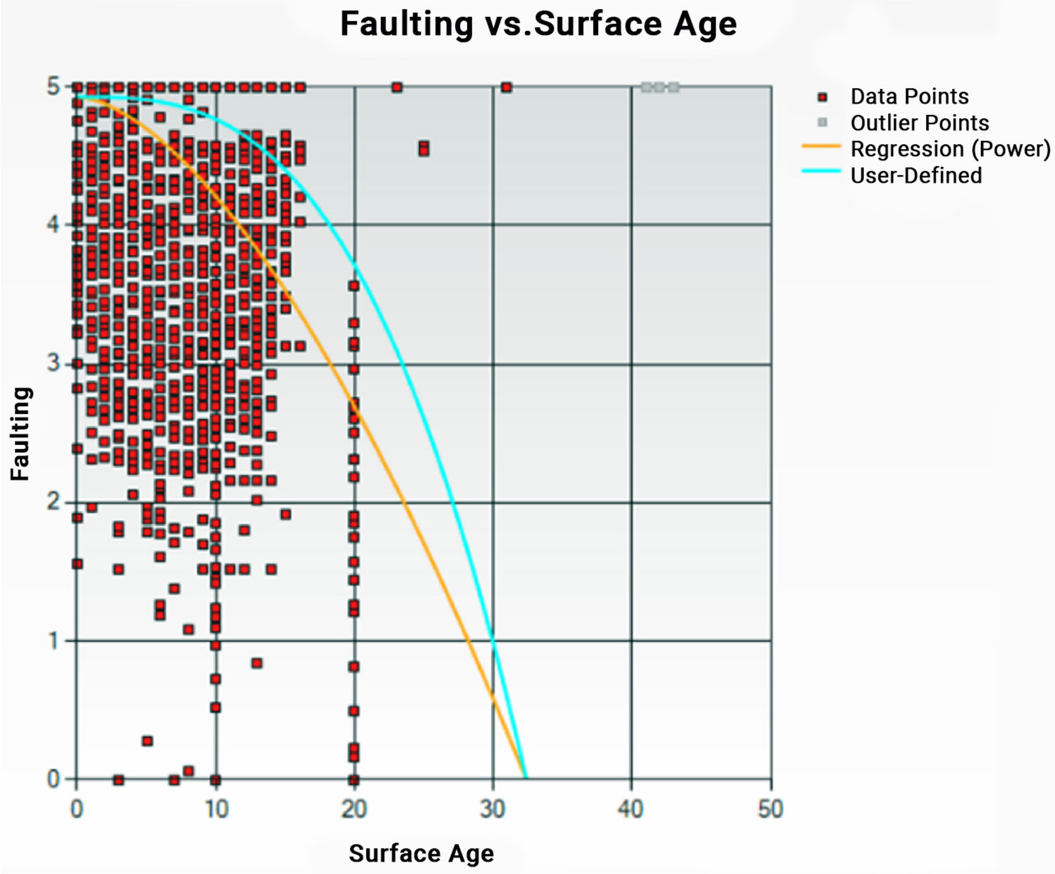


Illustration showing how historical data can be used to modify a deterioration model.
Source: South Dakota DOT. 2012. Technical Memo/Software Documentation

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.

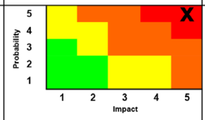
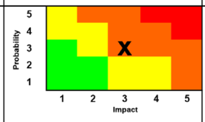
Risk Register

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.

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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Section 7.1
TAM Information Integration

Section 7.2
Collecting Asset Data

Section 7.3
Asset Data Sharing, Reporting and Visualization

Section 7.4
Data Governance and Management

Chapter 7
Information and Systems

Section 7.1

TAM Information Integration
covers the "big picture" of how TAM-related information fits with other information sources and systems in a transportation agency.

Section 7.2

Collecting Asset Data
covers asset data collection including guidance for what data to collect and how to collect it.

Section 7.3

Asset Data Sharing, Reporting and Visualization
covers data reporting and visualization – including essential activities for translating data into useful information.

Section 7.4

Data Governance and Management
covers data governance and management, including key roles and responsibilities needed to achieve reliable, integrated and accessible data for TAM.

Chapter 7 Information and Systems

TAM is naturally a data-driven activity; well-managed data and integrated information systems are keys to success. Asset data collection processes, management systems and reporting platforms are costly to implement and maintain. It is important to plan and design them in a deliberate fashion to serve decision making and reporting needs – while making them both maintainable and adaptable.

This chapter builds on the discussion of TAM information needs in Chapter 6. It covers processes and tools for TAM data collection, management, integration and reporting.

Key Terms

Business Intelligence (BI)
Practices and tools that enable access to and analysis of information to improve and optimize decisions and performance.

Data Governance
The accountability for the management of an organization's data assets to achieve its business purposes and compliance with any relevant legislation, regulation and business practice.

Data Integration
The planned and controlled transformation and flow of data across databases, for operational and/or analytical use. Data integration can involve multiple steps including access and extraction of data from source systems, validation and cleansing, transformation to a target structure, and finally, loading in to the target repository.

Data Management
The processes and activities in place to develop, implement and enforce policies and practices for protecting and enhancing the efficiency, value and effectiveness of data and information.

Data Warehouse
An integrated, centralized decision support database that stores cleansed and standardized data from a variety of operational sources to support analysis and reporting.

Linear Referencing System (LRS)
Linear referencing is a method for storing and managing geospatial information along a linear feature, with positional location defined by a distance measure along that linear feature. A Linear Referencing System aligns the linear reference points across multiple databases so information from different sources can be mapped and analyzed.

Section 7.1

TAM Information Integration

This section discusses the different information systems in a transportation agency and the need to connect data across these systems to provide an integrated view of information. It provides an overview of how to plan for system integration efforts – recognizing key integration points and data flows. It ends with a discussion of integrating data across the TAM life cycle.

This section has four parts:

1. **TAM Data and Systems**. Addresses the data and systems necessary to support TAM decision-making.
2. **Why Integrate?** Describes the benefits to be derived from integrated views of asset information.
3. **Planning for TAM Information Integration**. Discusses different levels of information integration and steps to strengthen integration.
4. **Integrating Asset Information Across the Life Cycle.** Addresses the use of tools, standards and processes to manage data for an asset over its entire life cycle from scoping and design through construction, maintenance and operation.

TAM Data and Systems

Often organizations maintain data on inventory, condition and needs for individual asset classes in separate, self-contained systems. However, increasingly it is necessary to integrate asset and related data distributed across multiple systems to support decision-making.

As discussed in Chapter 6, there are several different types of information needed for TAM decision making. These include:

- **Asset inventory and design information** including location, type, quantity, material, and design details. This also includes summary level information about the asset as a whole as well as information about individual asset components (e.g. different pavement layers or bridge elements). It may also include asset valuation information (calculated based on deteriorated replacement cost, historic cost, or fair market value).
- **Asset condition and performance information** including results of visual inspections, measured condition (such as roughness or cracking for pavements), and computed measures of performance (such as remaining service life or "deficient" status designation). This also includes aggregated network level measures (such as the percentage of pavement in good condition).
- **Contextual information** such as system or network characteristics, functional classification, highway geometric characteristics, traffic volumes, congestion and reliability, crash history, adjacent land uses, weather and features of the natural environment. This information is helpful for understanding factors that may impact the asset service requirements or goals, physical deterioration, funding eligibility, and/or project needs and constraints.
- **Work information** including date, cost and scopes of work proposed, scheduled and completed on assets – including installation, replacement/reconstruction, rehabilitation, preservation and maintenance. When projects include multiple assets, it is valuable to itemize the work performed by asset.
- **Revenue and funding allocation information** including historical and forecasted funds available for asset installation, replacement/reconstruction, rehabilitation, preservation and maintenance – by source; and historical allocations by asset category and work type.
- **Analysis information** including forecasted condition and needs under varying funding or program scenarios, treatment life or life extension results, or project prioritization ratings or rankings.

Agencies store and manage TAM-related data within several different information systems:

- **Asset Management Systems (AMS)** – this includes pavement management systems (PMS), bridge management systems (BMS), management systems for other specific asset classes (sign or signal management systems), and systems used to manage information for multiple asset classes. All of these systems are used to store inventory and inspection data, and track work performed on an inventory of assets. They also typically include contextual information needed for modeling and analysis, such as traffic, functional classification, number of lanes, and presence of a median. More advanced management systems may identify and forecast preservation and rehabilitation or replacement needs, and analyze funding scenarios. However, often agencies use multiple systems for this purpose, with separate systems for maintaining the asset inventory and predicting future conditions. Pavement and bridge management systems are typically used as the sources for federal Highway Performance Monitoring System (HPMS) and National Bridge Inventory (NBI) reporting.

- **Maintenance Management Systems (MMS)** – used to plan and track routine maintenance activities. These systems typically store information about planned and completed maintenance activities and resources (labor, materials, equipment) consumed. MMS may include customer work requests, work orders, and maintenance level of service (LOS) information. Some MMS do not store any asset inventory data. In such cases, work is tracked by maintenance activity category and route section rather than specific asset. Note that there are many commercial Asset Management Systems that provide full functionality for asset inventory, inspection/condition assessment, work planning, and work tracking.
- **Program and Project Management Systems (PPMS)** – used to manage information about capital and major maintenance projects from initial planning and programming through completion. There may be separate systems for managing programming/funding information, preconstruction/design information and construction phase information. Some agencies integrate data from these various systems to obtain a single source of project information. Project information typically includes a mix of tabular data as well as unstructured data (for example, documents and images). Unstructured data may be managed within an engineering content management system separately from other data.
- **Financial Management Systems (FMS)** – used to manage and track revenues, expenditures, budgets, grants, payments, receipts, and other financial information. These systems are often supplemented with special purpose tools supporting budgeting, revenue forecasting and analysis.
- **Enterprise Resource Planning Systems (ERP)** – incorporate features of financial systems as well as a wide variety of other modules for functions including human resources, payroll, purchasing, maintenance management, inventory management, equipment management, project programming, project financial management, and revenue forecasting.
- **Highway Inventory Systems (HIS)** – used to store and report administrative and physical characteristics of the roads and highways. Federal Highway Performance Monitoring System (HPMS) requirements and the Model Minimum Inventory of Roadway Elements (MIRE) define standard road inventory elements; some DOTs maintain additional elements. HPMS elements include pavement type, pavement condition (roughness, cracking, rutting and faulting), and structure type. These systems may include Linear Referencing System (LRS) management capabilities or, may be integrated with a separate LRS management system. Per FHWA's All Roads Network of Linear Referenced Data (ARNOLD) requirements, state DOTs must submit an LRS for all public roads to FHWA, linked to their HPMS data.
- **Crash Data Systems (CDS)** – used to store and report data about collisions and resulting injuries and fatalities; which when combined with traffic data and road inventory data provides information for identifying traffic and safety asset needs.
- **Traffic Monitoring Systems (TMS)** – used to store and report traffic data, required for federal reporting and used for a wide variety of purposes, including TAM processes for asset deterioration modeling, treatment selection and prioritization.
- **Engineering Design Systems (EDS)** – used to create design drawings or models including design details for different assets. As agencies adopt 3D object-based design modeling practices, there are opportunities to share information about assets between design models and other asset data systems used across the life cycle.

- **Enterprise Geographic Information Systems (GIS) –** used to manage spatial information, including asset location. Assets may be represented as point, linear or polygon features; location may be specified based on coordinates and/or based on a linear referencing system (LRS). Asset features maintained within GIS may be linked to asset information within other systems.
- **Imagery Databases (ID) –** used to store highway video imagery and mobile LiDAR data that can be used for manual or semi-automated extraction of asset inventory.
- **Data Warehouses/Business Intelligence Systems (DW/BI) –** used to integrate data from source systems for reporting and analysis. These may be tailored for TAM decision support.
- **Other –** there may be other specialized decision support tools that produce analysis results – for example, tools for life cycle cost analysis, cross-asset optimization, or project prioritization.

Table 7.1 provides an overview of different systems with the types of information they typically contain. Note that this may vary within each agency.

Table 7.1 TAM Data and Systems Overview (example)

	Asset Inventory, Condition and Performance	Contextual	Asset Work Information	Revenue and Funding Allocations	Analysis Results
Asset Management Systems	●	●	●	●	●
Maintenance Management Systems	●		●		●
Program and Project Management Systems			●	●	●
Financial Management/ERP	●		●	●	
Road Inventory Systems/HPMS	●	●	●		
Crash Databases		●			
Traffic Monitoring Systems		●			
Engineering Design Systems	●				
Enterprise GIS Databases	●	●	●		
Imagery Databases		●			
Data Warehouses/BI	●	●	●	●	●
Other					●

TIP Taking stock of what data and information systems supporting TAM is a critical first step to take before pursuing data integration and system development initiatives.

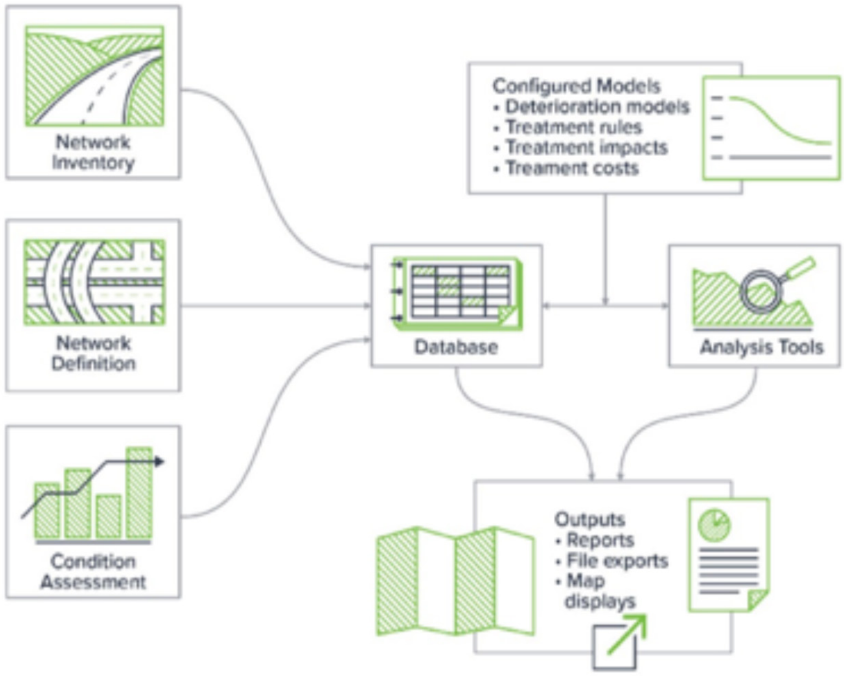
Common components included in computer-based asset management information systems are shown in Figure 7.1. Network inventory, network definition (e.g., location), and asset condition information serve as the primary components in a database, which may or may not be external to the management system. Agency-configured models are used to predict changes in asset condition over time and to determine what treatments are appropriate as the assets age and deteriorate. These models may be developed and updated based on historical condition and cost data.

When developing a computer-based model, an objective (performance, condition, financial, risk) must be defined within the model for it to evaluate these criteria to develop and select optimal strategies. Metrics such as benefit-cost, risk, condition and treatment costs are often used.

A typical pavement management system performs some type of benefit/cost analysis that determines the performance benefits (typically in terms of improved condition) and the costs associated with each possible treatment timing application. By selecting the projects and treatments with the highest benefit/cost ratio, an agency can demonstrate that it is maximizing the return on its investment.

Bridge management systems more typically rely on optimization to perform a single-objective analysis, such as minimizing life cycle costs or maximizing condition, or a multi-objective optimization analysis that considers factors such as condition, life cycle cost, risk of failure, and mobility. Project- and/or network-level benefit/cost analyses are used in a bridge management system to explore all feasible treatment options over an analysis to determine the most cost-effective set of treatments with the highest benefits to the network.

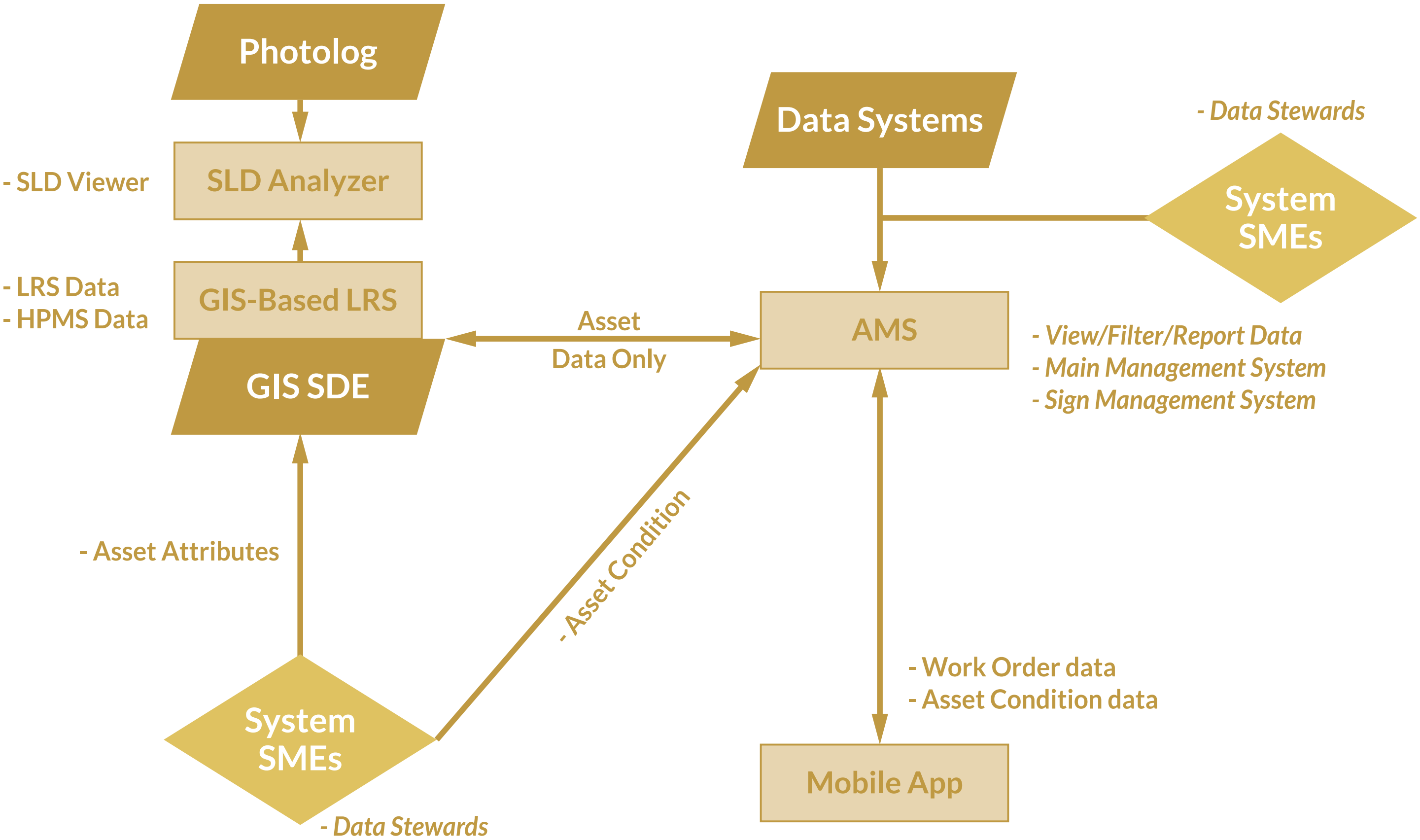
Figure 7.1 Typical Management System Components



TIP **Start by defining what questions the agency wants to answer and then make a plan for how data across systems could be integrated to answer these questions.**

Figure 7.2 shows an example of how the different systems listed in Table 7.1 might be integrated, adapted from the approach used by a U.S. state DOT.

Figure 7.2 Data Integration Example



Why Integrate?

Integrated views of asset information enable insights that lead to better decisions. Information produced by one part of the agency can support decision making across the agency.

Linking information across different systems enables agencies to quickly answer important questions that might have taken hours of staff time without integrated data. Integrating data opens up access to previously siloed data sets across the organization. It allows an agency to reduce duplicative effort, achieve efficiencies and derive greater value from its data. Some questions that rely on integrated data are:

Investments and Accomplishments

- What have we spent over the past ten years on route X in county Y (across all assets and including both maintenance and rehabilitation)?
- What percentage of deficient pavements will be addressed by our current capital and major maintenance programs?

Work Costing and Scoping

- What does it cost us to restripe a mile of pavement markings in each district?
- What locations identified along the linear referencing system (LRS) are planned for next year?
- Do the costs estimated by our pavement management system match what we are actually seeing in our projects?
- If we upgrade our guardrails whenever we do a paving project, how long will it take, and what will it cost to eliminate the current backlog?
- How can we best plan our projects to address multiple needs that may exist along a corridor?

Performance

- How many years does our standard mill and fill pavement treatment last for roads in different traffic volume categories?

Tradeoffs and Prioritization

- How should we prioritize our asset replacement/rehabilitation projects, considering not only life cycle management strategies but also stormwater management, safety, congestion, non-motorized, transit and ADA needs?
- How should we allocate our available funds across multiple asset types?

Disaster Recovery

- What assets were on route X in county Y prior to the storm? What will it cost to replace them?

An integrated approach to asset data collection, management and reporting not only makes it easier to answer these questions; it also can reduce costs. Opportunities for achieving efficiencies include:

- Using a single application to manage information about multiple assets.
- Using Data Warehouse/BI and GIS tools to provide reporting and mapping functions rather than investing effort to develop these capabilities within individual asset management systems.
- Gathering data on multiple assets through the same approach – using mobile technology, video imagery and/or LiDAR (see section 7.2)
- Sharing asset data across the life cycle

Practice Examples
Integrating Asset and Project Information

Ohio DOT

Ohio DOT has separate pavement and structures management systems, but integrates both asset and project information within its Transportation Information Management System (TIMS). A separate Transportation Asset Management Decision Support Tool (TAM-DST) allows for a user to combine data from TIMS with other state-maintained data sets to perform analysis and reporting. The application allows for one to consume large quantities of data in a timely manner to help make better choices in planning. See practice examples in Section 2.2.4 and Section 6.2.1 for more information on TIMS.

– for example, automating methods for extracting asset data from design plans to update asset inventories (described further below).

Emerging technologies and new data sources are making an integrated approach to asset data management even more important. For instance, there are increasingly opportunities to use data collected from cell phones and connected vehicles that may cut across many asset categories. Also, there has been and will likely continue to be rapid advancement in machine learning techniques, such as for extracting asset data from video imagery or predicting optimal maintenance interventions given a wide array of data. Using these techniques typically requires establishing large, integrated data sets.

In addition, advances in computer-aided design and engineering software are making it possible to integrate asset data across the life cycle and achieve efficiencies and cost savings in maintaining asset inventories. See the discussion in section 7.1.4 below.

Practical Benefits of Data Integration...

- Ability to maintain asset inventory in a single source system of record and share it with other systems that need it
- Ability to tap into road inventory data (e.g. functional class, NHS status, # lanes) without the need for duplicative data entry into asset management systems
- Ability to select current assets from a map for field inspection or work recording
- Ability to produce maps showing assets due for maintenance or replacement overlaid with locations of planned/programmed work
- Ability to produce trend lines of asset performance
- Ability to produce charts of current and projected asset performance versus target
- Ability to produce reports showing how the current construction program translates to improvements in asset condition or performance
- Ability to produce reports showing asset maintenance and replacement costs
- Ability to produce reports of average unit costs for different work types for different assets
- Ability to leverage data generated at different phases of the asset life cycle (planning/scoping, design, construction, maintenance and operation) within other phases.

TIP **Integrating information systems can be approached incrementally. Have a long term goal in mind and find opportunities to move towards this goal as systems are upgraded or replaced.**

Planning for TAM Information Integration

There are different levels of integration. In the short term, agencies can integrate the information they already have. In the longer term, agencies can modify and consolidate their information systems. Integrating data for TAM should be approached systematically to ensure agencies achieve a solution that meets their needs and is ultimately sustainable.

Step 1: Establish Requirements

What is the purpose of the integration? To create a publicly available map showing asset conditions and projects for both internal and public use? To create a BI environment for answering a range of questions about asset performance and cost? To integrate asset data across different systems used for planning, design, construction, and maintenance?

Based on the identified needs, determine what data will be integrated and at what frequency. Consider whether this will require historical data, current data, future projections, or a combination.

Early collaboration between business units and information technology units is important to establish a shared understanding of both business needs as well as technical requirements and constraints. A strong business-IT partnership is essential for successful information integration initiatives.

Step 2: Identify and Evaluate Data Sources

Identify the available data sources to meet requirements. Determine where the data reside, and in what form – such as engineering design systems, relational databases, spreadsheets, document repositories, etc. Assess the current level of data quality to make sure that the source is ready for integration, based on discussions with the data steward or through examining the data. For design files/models a key quality consideration is whether established standards have been consistently applied. It is also important to determine the level of spatial and temporal granularity – or what does each record represent (such as a pavement condition observation for a 0.1 mile section for April 2019; a paving project on a 1.5 mile section due to open for traffic sometime in 2020.)

Step 3: Analyze Linkages

Identify how different data sources will be linked. Spatial linkages are a good place to begin. If GPS coordinates are used, make sure that the Coordinate Reference System (CRS) used is documented, along with positional accuracy. If a Linear Reference was used, determine what method was used to establish the measure along the route, and what version of the agency's LRS was used to establish route identifiers and reference points. Find out if the linear reference has been updated to reflect changes in the LRS since the data were last collected (if applicable).

TIP **Set standards for how assets and work activities will be linked to GIS/LRS locations. Then create processes and tools to make sure these standards are followed.**

Identify other types of (non-spatial) linkages that may be needed to join different data sources – for example, project numbers, account codes, work order numbers, etc. Agencies may want to profile the data for these elements to understand variations in coding and formats.

Step 4: Design Data Flows and Select Technology Solutions

Based on the requirements, available data, the linkage analysis and the tools and resources available within the agency, design how the data will flow from sources to target systems, and select the technology solutions to be used for performing the integration itself. The target system might be a general purpose enterprise geodatabase, an enterprise asset management database, a BI tool reporting data source, data warehouse, or a data lake. Data Extract-Transform-Load tools are available from data warehouse vendors; simple integration tasks may be accomplished through scripting. There are also a variety of specialized tools available for transforming and combining spatial data, and for extracting data from CAD/3D models.

Step 5: Design and Implement Integration Methods

Develop the technical approach for transforming link fields so that they are consistent across databases and if applicable, joining the different data sets and combining common data elements from the different sources. This may involve spatial processing (such as dynamic segmentation), aggregation, coding conversions, and other transformations.

Short term integration strategies include:

- Creating GIS data layers and making them accessible in available web and desktop-based GIS software. This strategy requires that each data source uses compatible spatial referencing, or can be converted to a common referencing system.
- Creating a database or view combining data from various source systems, and using available BI/Reporting tools to create reports and data visualizations. This strategy requires identifying common “dimensions” across source systems and/or normalizing data so that it can be summarized. For example, if the agency wants to report asset quantities by district or county by year, it will be necessary to make sure that each source has these data elements and that the data can be converted to a consistent set of values.
- Exposing data from authoritative sources as services via Application Programming Interfaces (APIs).

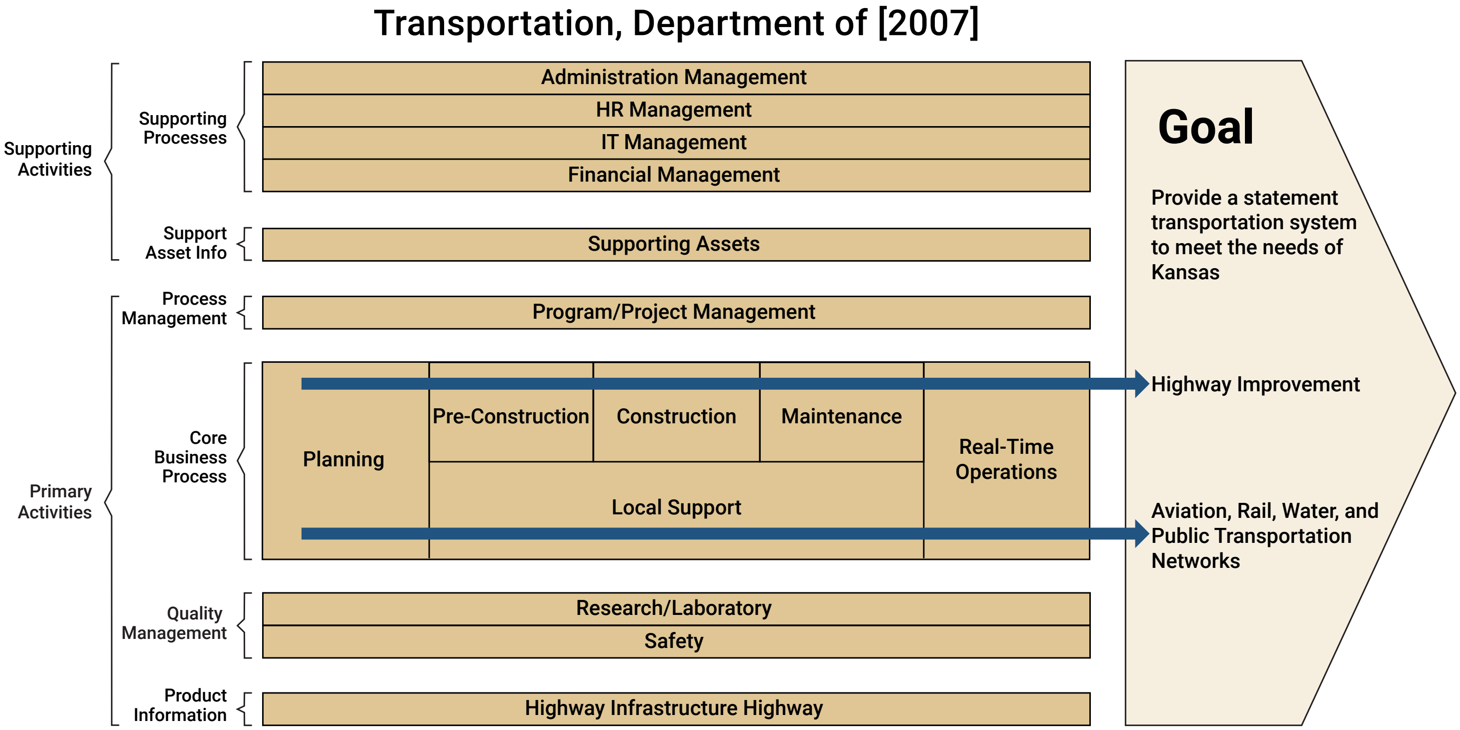
In the longer term, agencies can consider re-architecting or consolidating their systems so that they work better together. A logical way to approach this is to document the “as is” situation and then map out a “to be” architecture. This will allow the agency to chart a path from the current state to the desired future state. It will also provide a framework for capturing requirements for any new systems that are brought into the agency.

Integrated asset management systems are not a new concept and there are several commercial systems that support information management and work planning for multiple asset types. However, some agencies are challenged to integrate information about major assets (pavements and bridges) with information about various other ancillary assets – given that approaches to planning and budgeting for major assets are more sophisticated and require a greater level of detailed information and analysis. Also, it can be a challenge to integrate information about operations and maintenance with capital projects given differences in how work is categorized, performed, and tracked.

Practice Example

Kansas DOT • Enterprise Architecture Study

KDOT’s architecture was based on a value chain model that represents the agency’s business components and relationships. It included a set of “context diagrams” showing information flow across systems and actors for major subject areas including highway asset systems, long range planning, pre-construction, construction and maintenance. While an architecture does require significant effort to create and maintain, it provides a more global and stable view of business processes and information needs than what would be produced through a piecemeal, incremental approach to system upgrades and replacements. This view can be used to plan the path from the existing set of systems to a more efficient and integrated set.



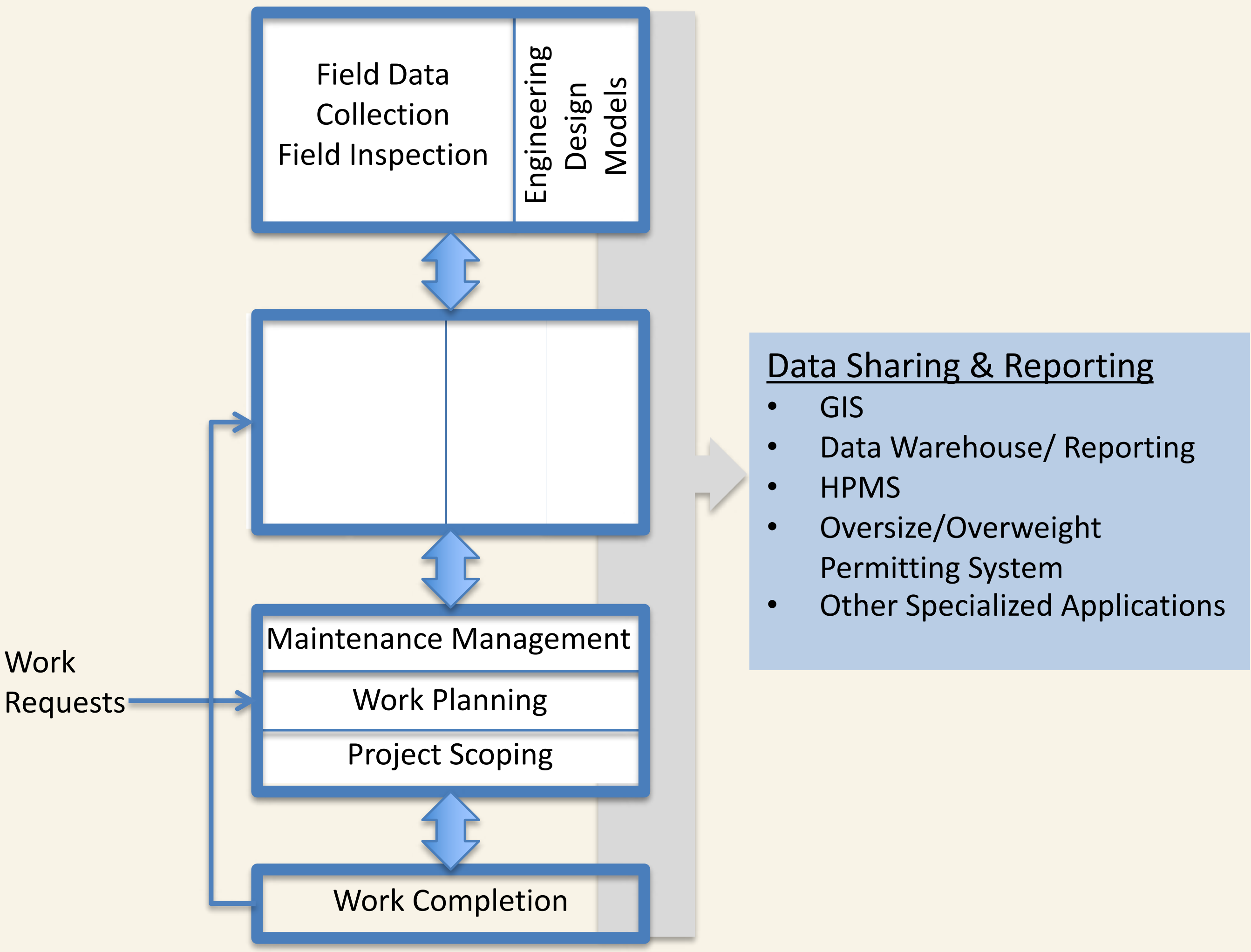
Kansas DOT Value Chain Framework

Source: Adapted from Kansas Department of Transportation. 2003. *Enterprise IT Architecture*

Sample TAM Data Flows

The figure below illustrates some of the data flows across TAM and related systems that agencies should plan for to integrate data.

- Road inventory to field data collection (information for routing)
- Asset inventory to field data collection (information about existing assets)
- Field data collection to asset inventory (updated inventory)
- Engineering design model to asset inventory (updated inventory based on new project)
- Asset inventory to project scoping (asset quantities)
- Asset inventory to maintenance management/work planning
- Asset inventory to GIS (updated asset locations)
- Asset inventory, condition and needs to Data Warehouse/ Reporting System
- Bridge inventory to HPMS (structure locations)
- Customer work request to maintenance management/work planning
- Field inspection to asset condition (updated condition)
- Pavement condition to HPMS
- Bridge inventory to oversize/overweight permitting
- Asset needs to work planning
- Work completion to asset inventory
- Work completion to asset condition



TIP Find opportunities to save on data collection costs by capturing asset information during project design and construction.

Checklist

Data Items to Standardize for TAM

Consider establishing standard definitions, code lists and formats for the following items.

- ☐ **Location of assets, projects, and maintenance activities.** Spatial (X,Y), linear reference, district/region, city/county
- ☐ **Asset ID.** A shared, unique identifier for an asset
- ☐ **Project ID.** A shared, unique identifier for a project, ideally maintained from "cradle to grave"
- ☐ **Asset Category/Type.** Based on an adopted agency naming convention
- ☐ **Asset work type.** A common set of categories for describing types of maintenance, repair, rehabilitation or replacement work performed. Ideally these are hierarchical, enabling roll-ups from detailed work types to shared work categories that can be used for reporting across asset types.
- ☐ **Asset Inventory units of measure.** Common inventory units include linear feet, square feet, 'each' and miles.
- ☐ **Asset Work units of measure.** These may be similar to inventory units but include things like tons of asphalt patching.
- ☐ **Resource types and unit costs.** Labor, equipment, materials, contracts
- ☐ **Project-Asset Linkage.** To identify which assets were included within a project
- ☐ **Maintenance Activity-Asset Linkage.** To identify assets (and quantities) were included within a maintenance activity
- ☐ **Work Status.** Proposed, planned/programmed, in progress, complete, open to traffic
- ☐ **Timeframe for work completion.** Multiple levels of granularity as needed for planning and reporting
- ☐ **Costs.** Standard methods of accounting for inflation; inclusion of ancillary costs such as construction engineering or traffic control; ability to compare estimates across systems
- ☐ **File naming conventions.** For linking standard documents to asset information
- ☐ **File formats.** Design data, multimedia data

Integrating Asset Information Across the Life Cycle

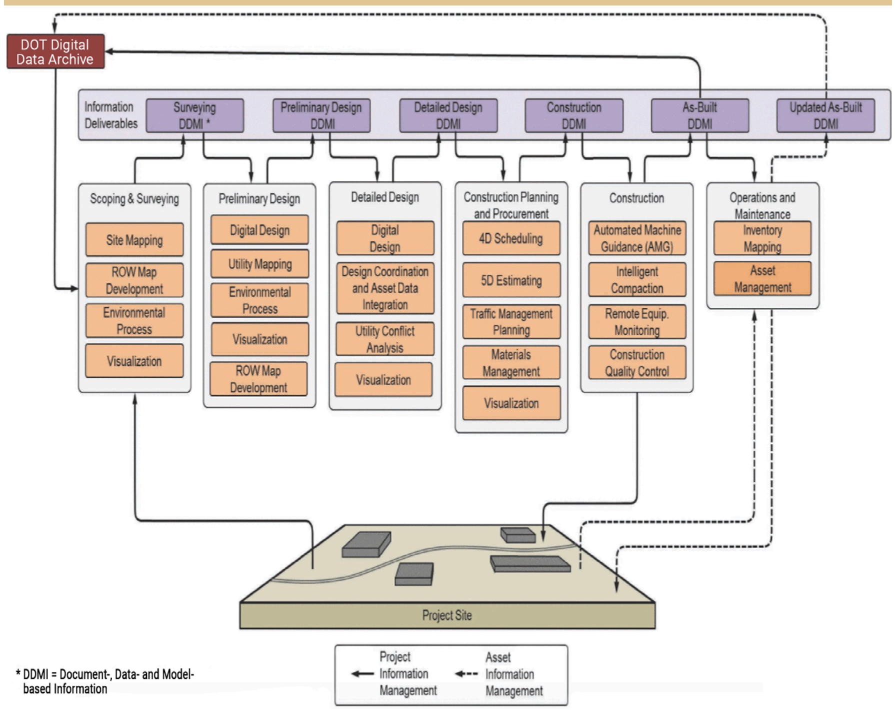
As assets are designed, created, maintained, restored, and replaced, different systems are typically used to keep records of asset characteristics, conditions and work. Ideally, information created at one stage of the asset life cycle is made available for use at the next stage. Techniques, tools and processes are available to manage data for an asset over its entire life cycle from construction or acquisition to disposal.

Integrating information across the transportation infrastructure life cycle is an area of significant interest in the transportation industry. Several terms have been used to describe the collection of processes, standards and technologies for accomplishing such integration – including Civil Integrated Management (CIM) and Building Information Modeling (BIM) for Infrastructure. In 2019 ISO issued its first BIM standard, ISO Standard 19650. This builds on an earlier standard published by the British Standards Institute (BSI).

Traditionally, information created at one phase of the life cycle is archived and not made available to downstream processes. There are substantial opportunities for cost savings by using a shared, electronic model of the infrastructure, defining information needs at each life cycle phase, and establishing procedures for information handoffs across the life cycle. For example, information about assets included in a construction project can be compiled during design and linked to the model representations of the assets. This information can be confirmed and corrected during construction and made available to asset management systems when the project is completed and turned over to maintenance and operation.

Such integration can reduce duplicative data collection efforts, and speed the time required to make decisions and perform work. Implementing these techniques requires much more than adoption of technology supporting 2D and 3D models. A commitment to common standards and processes is needed. Recognizing that this scale of change takes time, maturity models and levels of implementation have been defined to guide agencies in developing roadmaps for enhancing life cycle information integration over time. See the references at the end of this chapter for further information.

Figure 7.3 Integrated Workflow Model for Sharing Information Across the Life Cycle Components



Source: Transportation Research Board. 2016. *Civil Integrated Management (CIM) for Departments of Transportation, Volume 1: Guidebook*. https://www.nap.edu/read/23697/chapter/5#16

Practice Example

CrossRail • Application of Building Information Modeling (BIM)

Crossrail is a major design-build project to construct a new railway line across central London (UK). It includes 42 km of track and 10 new underground stations. Project construction began in 2009. The project is being delivered by Crossrail Limited (CRL), currently a wholly owned subsidiary of Transport for London (TfL). Once the project is complete it will be operated by TfL as the Elizabeth Line. The Crossrail project provides a good example of the application of several BIM elements. Early on, CRL established the following objective:

To set a world-class standard in creating and managing data for constructing, operating and maintaining railways by:

- Exploiting the use of BIM by Crossrail, contractors and suppliers
- Adoption of Crossrail information into future infrastructure management (IM) and operator systems

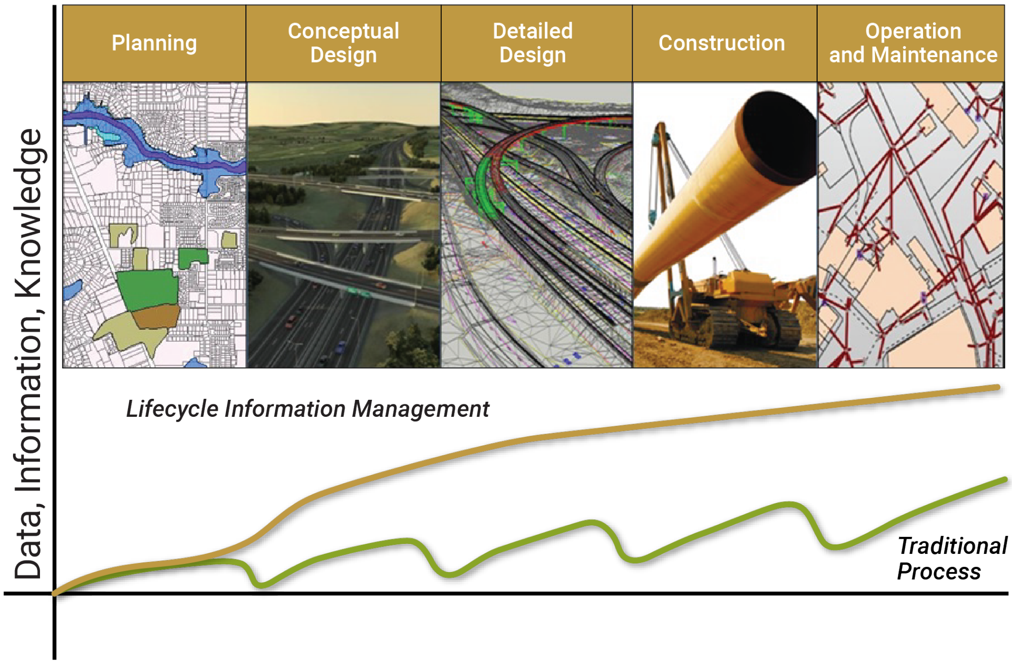
CRL established a Common Data Environment (CDE) with integrated information about the project and the assets it includes. This environment included CAD models, separate linked databases containing asset details, GIS data, and specialized applications for scheduling, risk management and cost management. Data warehousing techniques were used to combine and display integrated information. Considerable work went into defining asset data requirements and setting up standard, well documented data structures and workflows to provide an orderly flow of information from design through construction, and on to maintenance and operation. It was essential to create a common information architecture given that work on each of Crossrail's nine stations was conducted by different teams, each consisting of multiple contractors. Each station was comprised of over 15,000 individual assets.

Key elements of the approach included:

- A common asset information database with standard templates for deliverables. This database serves as the "master data source from which playlists of information can be created."
- An asset breakdown structure (ABS) that relates facilities (e.g. stations) to functional units (e.g. retaining walls) to individual assets (e.g. steel piles).
- Asset naming, identification and labeling standards that distinguish functional duty requirements (e.g. a pump is needed here) from specific equipment in place fulfilling these requirements.
- Asset data dictionary definition documents (AD4s) that lay out the specific attributes to be associated with different types of assets, based on the ABS.
- Sourcing of the asset data from design and as-built information.
- A Project Information Handover Procedure specifying the methods of data and information handover for maintenance and operations once the construction has been completed.
- Use of a common projected coordinate system for CAD and GIS data
- Use of a federated data model in which information was maintained within separate special purpose systems, with a common master data model enabling sharing and interpretation of data from the different sources. The master model included elements such as time periods, budget and schedule versions, organizations, data owners, contractors, milestones and key events.

Sources: https://learninglegacy.crossrail.co.uk/documents/building-a-spatial-infrastructure-for-crossrail/

https://learninglegacy.crossrail.co.uk/documents/crossrail-project-application-of-bim-building-information-modelling-and-lessons-learned/



BIM Life cycle Information Management
Source: Adapted from Crossrail. 2016. *Building A Spatial Data Infrastructure For Crossrail.* https://learninglegacy.crossrail.co.uk/documents/building-a-spatial-infrastructure-for-crossrail/

Section 7.2

Collecting Asset Data

This section discusses approaches to collecting and maintaining asset inventory and condition data. It builds on the discussion of monitoring requirements included in Chapter 6.

This section has three parts:

1. **Deciding What Data to Collect**. Provides information to help agencies identify information needs, estimate the costs to obtain and manage new data and determine whether the cost is justified.
2. **Deciding on a Data Collection Method**. Discusses the different approaches for collecting data and in what circumstances those different approaches should be used.
3. **Preparing for Data Collection**. Details the steps for preparing to collect data including coordinating with stakeholders, specifying what data will be collected, and training staff in how data collection should be performed.

Deciding What Data to Collect

Many organizations have recognized that data should be viewed as an asset. Before acquiring new data, it is important to establish a clear statement of how the data will be used and what value it is expected to provide.

Deciding what data to collect involves identifying information needs, estimating the full costs of obtaining and managing new data and keeping it up to date, and then determining whether the cost is justified. Just as agencies don't have unlimited resources to repair and replace their assets, there are also limitations on resources for data collection and management.

A 2007 World Bank Study [1] summarized three guiding principles for deciding what data to collect:

- Collect only the data you need;
- Collect data to the lowest level of detail sufficient to make appropriate decisions; and
- Collect data only when they are needed.

Chapter 6 can be used to help identify the information needed to track the state of the assets and investments to maintain and improve them. The basic questions one needs to answer to identify needed data are:

- **What decisions do we need to make and what questions do we need to answer that require asset data?** Typically, an organization needs to be able to answer questions including but not limited to its asset inventory, the conditions and performance of the inventory, and how resources are being spent on its assets. Also, an organization needs to determine what work is needed and how much that work will cost.
- **What specific data items are required or desired?** Next, one must identify the data required to meet the established information needs. There may be other data items that are not strictly required, but that may be useful if collected in conjunction with the required data. For instance, answering questions and making decisions regarding pavement an organization would typically want to have an inventory of existing pavement, details on paving materials used, and details on current conditions. Additional information on treatment history or substructure conditions might not be strictly required, but if available could enhance the decision-making process.

  It is also important to incorporate standard data elements for location and asset identification into requirements, ensuring consistency with other asset data in the agency.
- **What value will each data item provide?** It is important to distinguish "nice to have" items from those that will clearly add significant value. The cost of collecting and maintaining a data element should be compared with the potential cost savings from improved decisions to be made based on the element. Cost savings may be due to asset life extension, improved safety, reduced travel time, or internal agency efficiencies. In addition, proxy measures for information value can be considered such as the number and type of anticipated

1 http://siteresources.worldbank.org/INTTRANSPORT/Resources/07-02-12DataCollectionTechnologiesReport-v20.pdf

Practice Example
Data Collection Tiers

Oregon DOT

- **Tier 1:** Assets with high replacement values and substantial potential cost savings from life cycle management (e.g. pavements and bridges)
- **Tier 2:** Assets that must be inventoried and assessed to meet legal obligations (e.g. ADA ramps, stormwater management features)
- **Tier 3:** Assets with high to moderate likelihood and consequences of failure (e.g. traffic signals, unstable slopes, high mast lighting, sign structures)
- **Tier 4:** Other assets that would benefit from a managed approach to budgeting and work planning (e.g roadside signs, pipes and drains)

TIP Look for ways to "collect once, use multiple times" by leveraging existing data and planning data collection efforts to capture information about multiple assets.

users, and the number and type of agency business processes to be impacted.

- **What level of detail is required in the data?** Level of detail is an issue for all assets, but is particularly an issue for linear assets such as pavement, where one may decide to capture data at any level of detail. For instance, to comply with Federal reporting requirements for pavement condition a state must collect distress data at 1/10 mile intervals for one lane of a road (typically the outside line in the predominant direction). For other applications it may be necessary to collect data for additional lanes, or at some other interval.
- **What level of accuracy is needed?** The degree of accuracy in the data may have a significant impact on the data collection cost and required update frequency. Ultimately the degree of accuracy required in the data is a function of how the data are used. For instance, for estimating the clearances under the bridge for the purpose of performing a bridge inspection it may be sufficient to estimate the clearance at lowest point to the nearest inch using video imagery. However, more accurate data may be required when routing an oversize vehicle or planning work for a bridge or a roadway underneath it. If a high degree of accuracy is not required it may be feasible to use sampling strategies to estimate overall conditions from data collected on a subset of assets.
- **How often should data be updated?** Is the data collection a one-time effort, or will the data need to be updated over time? If data will need to be updated should the updates occur annually, over a period of multiple years, or as work is performed on an asset?

Table 7.2 below illustrates examples of data collection strategies that might address different information needs.

Once a general approach has been established, more detailed planning for what data elements to collect is needed. Prior to selecting data elements, identify the intended users and uses for the data, keeping in mind that there may be several different uses for a given data set. Identify some specific scenarios describing people who will use the information, and then validate these scenari-

Table 7.2 Example Data Collection Strategies

Example Asset(s)	Type of Information	Example Decisions	Example Data Collection Strategies
Pavement Markings	Total asset quantity by type, district and corridor or subnetwork	Budgeting for assets maintained cyclically	Estimation based on sampling Full inventory every 3-5 years with interim updates based on new asset installation
Roadside Signs	Inventory of individual assets – location and type	Work planning and scheduling for assets maintained cyclically Project scoping	Full inventory every 3-5 years with interim updates based on new asset installation
Guardrail	Inventory + General Condition (e.g. pass/fail or good-fair-poor)	Work planning and scheduling for assets maintained based on condition	Inventory and condition assessment every 2-3 years Inventory and continuous monitoring (e.g. from maintenance crews or automated detection)
Bridges	Inventory + Detailed Condition	Treatment optimization for major, long life cycle assets	Inventory and condition assessment every 1-2 years + continuous monitoring (e.g. strain gages on bridges)

os by involving internal stakeholders.

One common pitfall in identifying information needs is failing to distinguish requirements for network level and project level data. While advances in data collection technology make it feasible to collect highly detailed and accurate information, it is not generally cost-effective to gather and maintain the level of information required for project design for an entire network of assets.

A second pitfall is failing to consider the ongoing costs of updating data. The data update cycle can have a dramatic impact on data maintenance costs. Update cycles should be based both on business needs for data currency and how frequently information is likely to change. For example, asset inventory data is relatively static, but condition data may change on a year-to-year basis.

A third common pitfall is taking an asset-by-asset approach rather than a systems approach in planning for both asset data collection as well as downstream management of asset information.

Even when there is a strong business case for data collection, it is sometimes necessary to prioritize what data are collected given budget and staffing constraints. Some agencies do this by establishing different "tiers" of assets. For example:

- **Tier 1:** Assets with high replacement values and substantial potential cost savings from life cycle management (such as pavements and bridges)
- **Tier 2:** Assets that must be inventoried and assessed to meet legal obligations (such as ADA ramps, stormwater management features)
- **Tier 3:** Assets with high to moderate likelihood and consequences of failure (such as traffic signals, unstable slopes, high mast lighting and sign structures)
- **Tier 4:** Other assets that would benefit from a managed approach to budgeting and work planning (such as roadside signs, pipes and drains)

While updating data can be expensive, various strategies are available for combining data collection activities to reduce the incremental cost of collecting additional data. For instance, one approach to collecting data on traffic signal systems is to update the data when personnel perform routine maintenance work. Also, in some cases data can be extracted from a video log captured as part of the pavement data collection process.

Given limited resources for data collection, it may be helpful to formally assess the return on investment from data collection or prioritize competing data collection initiatives. A formal assessment may be of particular value when considering whether the additional benefits from collecting additional data using a new approach justify the data collection cost. NCHRP Report 866 details the steps for calculating the return on investment (ROI) from asset management system and process improvements, including asset data collection initiatives.

How to Collect Data

As technology continues to advance there are more methods available for collecting data related to assets. It is important for agencies to understand the technology and options available for data collection. Depending on the asset-type or data needed, a different data collection approach may be preferable. This section provides information on making that decision.

There are many different approaches to collecting asset and related data. Often a mix of approaches is used, including visual inspection, semi-automated and automated approaches. The technologies for data collection are advancing rapidly, allowing for increased use of semi-automated and automated approaches for collecting more accurate data at a lower cost. Examples of recent innovations include:

- Improvements in machine vision that allow extracting some forms of asset inventory data from video or LiDAR.
- Use of unmanned aerial vehicles (UAV, also called drones) for allowing bridge inspectors to obtain video of hard-to-reach areas of a bridge.
- Improvements in non-destructive evaluation (NDE), allowing for greater use of techniques such as ground penetrating radar (GPR) for pavement and bridge decks and instrumenting bridges to monitor performance over time.
- Improvements in hand-held devices allowing for increased field use, reducing cost and time of manual data collection.

Several of these technologies provide opportunities to save money by collecting data for multiple assets within a single collection effort. Table 7.3 provides a summary of potential data collection approaches for common roadway asset classes.

Once data are collected, it is essential to put in place regular processes for updating the

Practice Examples

Cost Savings through UAV Bridge Inspection • Michigan DOT

Unmanned Aerial Vehicles (UAVs) offer several advantages for asset data collection. They can fly into confined spaces such as entrances to sewers and culverts to collect data and images. They can collect high resolution images, thermal images and LiDAR. LiDAR can be used to produce three dimensional images that allow for accurate measurements. Thermal images can be used to detect subsurface concrete deterioration.

Michigan DOT analyzed the benefits of using UAVs for bridge inspection, and concluded that using a UAV for a deck inspection of a highway bridge reduces personnel costs from $4600 to $250. A traditional inspection would take a full day and require two inspectors, and two traffic control staff to close two lanes of traffic. The same inspection using a UAV take 2 hours and would require only a pilot and a spotter. An additional savings of $14,600 in user delay cost was estimated based on delays associated with shutting down one lane of a four lane, two way highway bridge in a metropolitan area for a bridge inspection.

Use of LIDAR For Roadway Asset Inventory • Tennessee DOT

The Tennessee DOT uses an automated data collection van to collect pavement condition surveys each year in support of its pavement management system. In addition to the pavement sensors, the van also has high definition cameras and LIDAR sensors which scan the roadway and create a 3D model of the environment. As the surveys are conducted, inventory information for approximately 20 highway assets is extracted from photolog and LiDAR information. The inventory from the past data collection cycle is compared to the data collected during the current data collection cycle to determine any changes to asset inventory to keep the data up to date. Tennessee DOT summarizes this inventory data at the county level for planning and budgeting; however, they are currently working toward having the ability to report maintenance work at the asset level in the future. Federal Highway Administration (FHWA). Pending publication 2019. Handbook for Including Ancillary Assets in Transportation Asset Management Programs. FHWA-HIF-19-068. Federal Highway Administration, Washington D.C Federal Highway Administration (FHWA). Pending publication 2019. Handbook for Including Ancillary Assets in Transportation Asset Management Programs. FHWA-HIF-19-068. Federal Highway Administration, Washington D.C.

TIP **Before collecting new data, make sure you are leveraging data that already exists or is already collect ed, and coordinate with other agency groups that may have a need for the same data.**

data. This can be accomplished through periodic data collection cycles, or through updating as part of asset project development and maintenance management processes.

Table 7.3 Example Data Collection Approaches

Asset Class	Data Collection Method	Data Collected	Notes
Pavement	Visual inspection	Present Serviceability Index (PSI)	Often used in urban environments or for small networks where data collection using automated collection approaches is impractical – can be supplemented by UAVs
	Automated data collection vehicle with laser scanning system	roughness, cracking, rutting	Includes a range of 2D video and 3D laser-based systems. Many systems store video images and can capture additional measures, such as cross slope, gradient and curvature
	Light Detections and Ranging (LiDAR)/ Terrestrial Laser Scanning (TLS)		Provides a high resolution continuous pavement survey. Often inventory data for other assets can be extracted from the data set
	Falling weight deflectometer	strength/deflection	
	Locked wheel tester/spin up tester	skid resistance	
	Ground Penetrating Radar (GPR)	layer thicknesses, detection of voids and crack depth	
	Coring		
	Smart phones	potholes, roughness	Includes systems for reporting of potholes and measuring roughness through crowdsourcing
Structures and Bridge	Sensors	inventory, condition ratings	Strain and displacement gauges; wired or wireless,
	Unmanned Aerial Vehicles (UAVs)	condition of non-bridge structures (e.g. retaining walls)	
	LiDAR	Vertical Clearance	
	Visual	inventory, condition ratings	Can be supplemented using UAV and other technologies
	Acoustical (e.g., impact echo)	delamination, corrosion	
	Infrared/ Thermal Imaging		
	GPR	concrete deck condition	
	Half Cell Potential Test		
Traffic Signs	Videolog	inventory, condition ratings	automated or semi-automated techniques available for classification
	Mobile LiDAR		
	Field Inspection – mobile application		
	Retroreflectometer	retroreflectivity	

Preparing for Data Collection

In order to get the most out of the data collection process, it is important for agencies to be thoughtful in the steps leading up to the actual collection of data. Three important steps to prepare for data collection include: coordinating with stakeholders, specifying exactly what data will be collected, and training staff to collect the data.

Once an organization has determined what data to collect and how to best to collect it, the next step is to prepare for data collection.

Step 1. Coordinate

On important step prior to collecting data is to coordinate with other stakeholders in the organization concerning the data collection effort. It may be possible, through such coordination, to identify opportunities for coordinating data collection activities to reduce costs. Alternatively, other stakeholders may identify needs for collecting related data to address other needs. Another possibility is that a different business unit in the organization has already collected data that may impact the data collection plan.

Step 2. Specify

In this step one must identify exactly what data will be collected, the means used to collect the data, and who will collect the data. If data collection is being outsourced, at this point it is necessary to establish contract specifications for data collection.

Also as part of this step one should establish the approach for quality assurance (QA)/quality control (QC). A QA/QC plan specifies the desired accuracy of the data to be collected, and describes the measures used to assure data are of the specific level of accuracy, review data quality as data are acquired, and address any data quality issues that arise. If data are collected using automated means, the plan should specify the approach for calibrating any measurement devices used for data collection. If data are collected through visual inspection the plan should detail training requirements.

Note that given data QA/QC is an area of particular concern for pavement condition data collection, given the expense involved in collecting this data and increased reliance on automated data collection techniques. The Federal performance management requirements described previously include a requirement for State DOTs to establish a QA/QC plan for pavement data collection.

Step 3. Contract

This step involves determining whether to outsource data collection and to contract for services if applicable. Decisions to outsource are typically made to tap into a vendor with specialized equipment and experience with a particular data collection technique, and to enable accomplishing a major collection effort within a compressed timeframe, which would not be possible using internal staff resources. Some agencies may implement a hybrid approach, hiring a contractor while using internal staff (or a separate independent contractor) for supervisory or QA functions.

Step 4. Train

The last step prior to collecting data is to train the staff involved in data collection and review in how data collection should be performed, as well as in their specific roles

Practice Examples
Integrated Approach to Data Collection

Utah DOT

Utah DOT started capturing LiDAR data for multiple assets in 2011. Several different business units within the agency provided funding for the effort, which has included collection of inventory data for bridges, walls, signs, signals, barriers, power poles, striping, curb cuts, drainage, shoulders and ATMS devices – as well as pavement condition and roadway geometrics. UDOT has leveraged this integrated pool of asset data for several different applications, including one which creates a draft cost estimate for asset installation for project scoping, based on existing inventory.

TIP Understand your audiences and the questions they are trying to answer.

and responsibilities. Training is important for any data collection effort, but is particularly important in cases where the collection effort relies on visual inspection (for inspecting bridges). In these cases, the training requirements for inspectors should be carefully established and implemented. Even where there are no formal requirements for inspectors, it can be highly valuable to assemble inspectors prior to the start of data collection to review the data to be collected, walk through the data collection process, and perform inspections in a test scenario to ensure consistent interpretation of condition assessment language and other areas where differences in human judgement may impact how data are collected.

Once these steps have been performed the next step is to collect data, following the approach established in Step 2 for data collection and QA/QC.

Checklist

Asset Data Collection Readiness Checklist

Agencies can use this checklist when adding a new asset to the data collection, data management, and data governance processes. Addressing the items in this checklist will ensure that information about the asset is collected, used and updated efficiently and effectively within the agency.

- ☐ **Has asset owner or steward been identified?**
- ☐ **What asset category/type does this asset belong to?**
- ☐ **What is the precise definition of this asset?**
- ☐ **What are the asset's components?**
- ☐ **What are the units of measure for the asset?**
- ☐ **Has a data dictionary of attributes for this asset been developed?**
- ☐ **Who will use the data about this asset and how?**
- ☐ **Which attributes are needed to meet state or federal requirements?**
- ☐ **What method(s) will be used to collect inventory data for this asset?**
- ☐ **Will the data collection method and accuracy be included in metadata?**
- ☐ **What method(s) will be used to update inventory data for this asset?**
- ☐ **Have the data collection and updating technologies been investigated?**
- ☐ **Have the data collection manuals and other training materials been created?**
- ☐ **What method will be used to uniquely identify this asset?**
- ☐ **What method will be used to identify this asset's location?**
- ☐ **Will this asset be represented in GIS as a point, line or polygon?**
- ☐ **What method will be used to synchronize this asset's location with the agency's official linear referencing system?**
- ☐ **Is there a plan for data sharing and reporting?** For example, including the new data in an agency data warehouse or GIS portal?

Checklist

Asset Data Collection Readiness Checklist

- ☐ How will this asset's condition be assessed and described?
- ☐ What system(s) will store inventory and condition data for this asset?
- ☐ What types/categories of treatments are applicable for this asset?
- ☐ What are the units of work accomplishment for these treatments?
- ☐ What system(s) will store information about needs, planned work, and completed work for this asset?
- ☐ How will different agency and external users obtain data about this asset, its condition, needs, planned work, and completed work?
- ☐ Who is the point of contact for answering questions about data for this asset?

Section 7.3

Asset Data Sharing, Reporting, and Visualization

This section covers approaches to sharing, reporting and visualizing asset data to support agency decision making. It builds on the discussion of TAM Information Integration in section 7.1 and focuses on how to get value from the integrated data. This involves careful planning to define the needs of different users and design ways of delivering and sharing data to meet varying needs.

This section has three parts:

1. **Designing Effective Reports and Visualizations**. Data can be used in many ways to drive results and decisions within an agency. This section provides information on how reports and visualizations can help to effectively communicate data to intended audience.
2. **Data Sharing**. Depending on the intended user, data sharing techniques may differ. This section provides information on principles for data sharing, and processes for preparing data for sharing, reporting, and visualization.
3. **Preparing Data for Sharing, Reporting and Visualization.**

Designing Effective Reports and Visualizations

A wide variety of reports, maps, charts and infographics can be produced to convert raw data into actionable information. Designing effective reports and visualizations begins with a good understanding of who will be consuming the information, what their questions are, and what key messages the agency wants to communicate.

Different types of information users for asset data and sample questions they may have are shown in Table 7.4. This can be used as a starting point for identifying what types of reports and visualizations should be created. Keep in mind that increasingly, reports and visualizations are not static – they include multiple options for filtering, sorting and navigating information.

Some reports/visualizations are primarily for analysis, exploration and insight; others are primarily for communication. Some may be designed for both purposes. Those designed for analysis should emphasize flexibility – with multiple options for viewing, filtering, sorting, and exporting to various formats. Those designed for communication should emphasize simplicity and clarity of message; and clean, aesthetically pleasing design. They should reflect what the agency wants people to learn or know.

All reports/visualizations should include information that helps the user to understand:

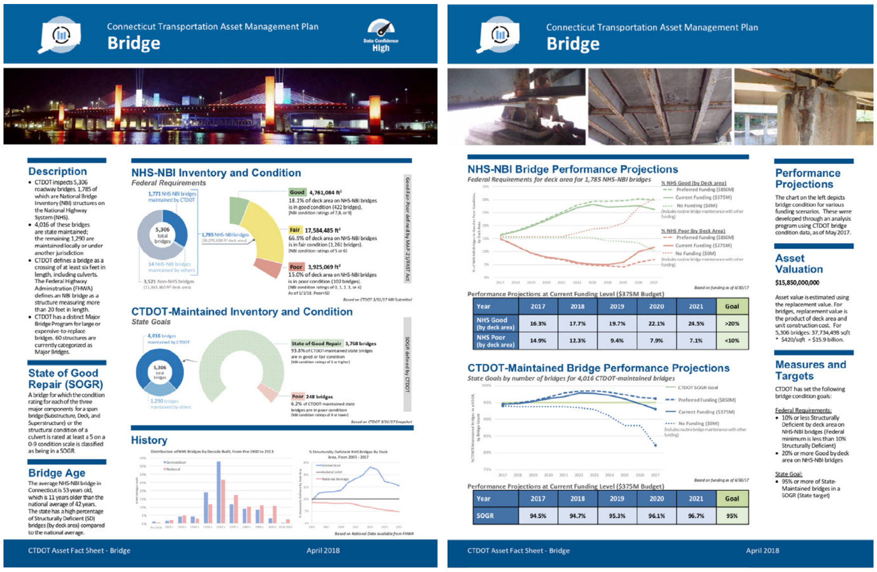
- the sources of the data being presented and the effective date for the data (e.g. what calendar year is represented)
- the assumptions used for any calculated items
- definitions of any acronyms or potentially unfamiliar terms
- who to contact for further information

A wide array of tools and techniques are available for reporting and visualization – tabular reports, maps, charts, dashboards, infographics, and combinations. GIS is an essential visualization tool with many applications and can be integral to information presentation. While some visualizations can be produced using standard office applications, many agencies use desktop publishing and business intelligence offerings. There are several general resources available on design of effective visualizations – see the reference list at the end of this chapter. Chapter 6 contains additional examples of data visualizations.

Practice Example

Connecticut DOT • Visualizing Asset Performance at Glance

To complement the Connecticut TAMP, Connecticut DOT (CTDOT) developed a series of asset Fact Sheets providing at-a-glance summaries of asset inventory and condition, State of Good Repair definitions, performance projections, targets and asset valuation for bridges, pavements, and five additional assets included in the TAMP. The asset Fact Sheets pair simplified graphs and other information displays with supporting contextual detail; a format that helps communicate CTDOT's TAM approach to policy makers, executives, and other non-technical stakeholders.



Source: Connecticut DOT. 2018. Asset Fact Sheet.

Table 7.4 Information Needs of Different Users

User Type	Sample Questions	Types of Reports/Visualizations
Analyst	Are the asset locations in this new inventory valid?	Map showing asset locations Report listing asset locations outside of the ranges of valid route-milepoint/mileposts.
	Are the observed changes in asset condition from the last inspection reasonable?	Time series plot/grid of asset condition + intervening project/maintenance activities
	What is the expected service life for asset X? What are the key factors impacting service life?	Minimum, maximum, mean, median life for selected asset type – with breakdowns by subtype (e.g. concrete versus asphalt pavement), last treatment, geographic region, road class. Map of assets with low (e.g. 25th percentile) lives with available information on contributing factors (e.g. reported drainage issues, soil quality, materials, contractor, use of road salt, etc.)
Asset/Maintenance Manager	What is the state of my asset(s)?	Fact sheet showing inventory, condition distribution, age distribution, value, performance projections and targets (if applicable)
	Which assets should be considered for treatment?	Map and listing of assets showing condition information and (if available) assigned treatment need – overlaid with programmed work. Drill down to condition and work detail.
	What should I budget for preventive maintenance?	Report showing asset quantities, unit cost for preventive maintenance, planned maintenance interval, and average annual cost over 5 year period. Separate report to inform selection of a unit cost – historical cost per unit of work or historical labor/equipment/materials utilization per unit of work.
Project Engineer	What assets are within the footprint of a project I am scoping?	Listing of assets and associated quantities for a defined location (route/from MP, to MP)
	Are there opportunities to coordinate work?	Map showing identified needs, proposed projects, programmed projects.
Executive	What have we been spending to maintain our assets?	Time series chart showing expenditures with breakdown by asset type, work type (maintenance versus capital), district/region. Display asset quantities and conditions on same time scale to compare expenditures against results.
	What is our backlog of needs?	Chart showing current needs backlog for selected assets – with available breakdowns by district/region, road class, asset type. Accompanying chart showing 5-10 year changes in backlog and projected backlog given revenue and funding allocation assumptions.

Table 7.4 Information Needs of Different Users (continues)

User Type	Sample Questions	Types of Reports/Visualizations
Executive	How do asset conditions compare across districts/regions?	Infographic showing asset condition (Good-Fair-Poor) bar charts superimposed on map of districts/regions.
	How should we allocate our available funding across different assets/projects?	Charts showing results of investment versus performance analysis Charts showing allocation and performance results of a prioritization exercise with drill down to prioritized project lists.
Funding/Oversight Agency (State/Federal)	How does the current and projected asset condition compare to the established target?	Trend line showing current and projected conditions under different funding scenarios with separate line for target.
	How do the actual pavement and bridge program accomplishments compare to those that were planned?	Chart showing planned, actual, percent difference and explanation.
General Public	When will my street be paved? When will the bridge replacement project be completed? How is the DOT using its funding?	Map showing programmed projects with status/schedule/funding information

Data Sharing

There are many different ways to share information about assets, condition, performance, needs, and work. Agencies can select multiple distribution channels to serve both internal and external users.

As with the design of reports and visualizations, designing a data sharing strategy should begin with an understanding of the different audiences for data and their needs. A variety of options for data sharing are available that can be employed. Table 7.5 outlines some of these options and suggests some questions to consider in selecting an appropriate option.

It is helpful to establish guiding principles for data sharing in order to achieve a consistent agency approach that provides maximum benefits in a cost-effective manner. Possible principles include:

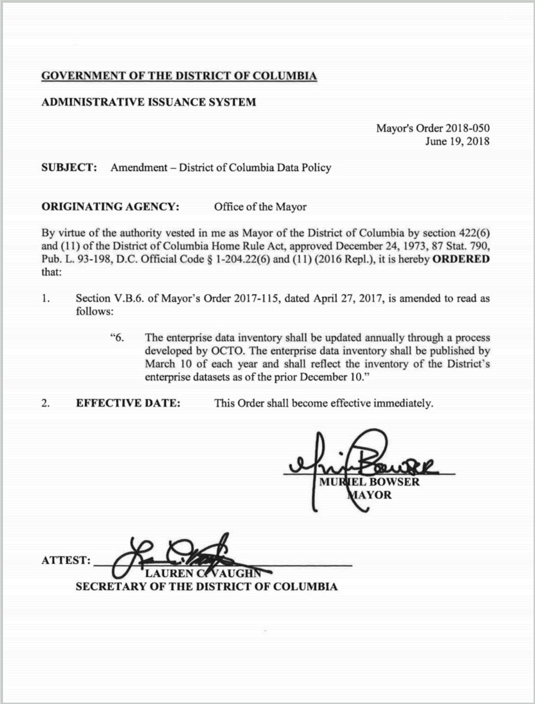
- By default, data should be shared unless it is sensitive, protected by law or if sharing it would pose unacceptable risks or cost burdens
- Self-service methods of data sharing should be used when there is a relatively large pool of data users and data limitations can be readily communicated via standard metadata
- Avoid proliferation of single purpose data sharing applications by adopting standard platforms where multiple data sets can be shared
- When it is necessary to share the same data set through multiple channels, the source data should be stored in a single location or a single data refresh process should be used to reflect updates
- The process of preparing data for sharing, reporting and visualization should be governed to ensure quality, ensure adequate documentation, and avoid inconsistency

Practice Example

DC DOT • Data Categories

Washington, DC has established four levels of data. By default, data is considered to be open and sharable.

- **Level 0.** Open (the default classification)
- **Level 1.** Public, Not Proactively Released (due to potential litigation risk or administrative burden)
- **Level 2.** For District Government Use (exempt from the Freedom of Information Act but not confidential and of value within the agency)
- **Level 3.** Confidential (sensitive or restricted from disclosure)
- **Level 4.** Restricted Confidential (unauthorized disclosure can result in major damage or injury)



GOVERNMENT OF THE DISTRICT OF COLUMBIA

ADMINISTRATIVE ISSUANCE SYSTEM

Mayor's Order 2018-050
June 19, 2018

SUBJECT: Amendment – District of Columbia Data Policy

ORIGINATING AGENCY: Office of the Mayor

By virtue of the authority vested in me as Mayor of the District of Columbia by section 422(6) and (11) of the District of Columbia Home Rule Act, approved December 24, 1973, 87 Stat. 790, Pub. L. 93-198, D.C. Official Code § 1-204.22(6) and (11) (2016 Repl.), it is hereby **ORDERED** that:

1. Section V.B.6. of Mayor's Order 2017-115, dated April 27, 2017, is amended to read as follows:

   "6. The enterprise data inventory shall be updated annually through a process developed by OCTO. The enterprise data inventory shall be published by March 10 of each year and shall reflect the inventory of the District's enterprise datasets as of the prior December 10."

2. **EFFECTIVE DATE:** This Order shall become effective immediately.

MURIEL BOWSER
MAYOR

ATTEST:
LAUREN C. VAUGHN
SECRETARY OF THE DISTRICT OF COLUMBIA

Source: https://octo.dc.gov/page/district-columbia-data-policy

Practice Example

Vermont Agency of Transportation (VTrans) • Data Sharing

VTrans shares their data with the public through the VTransparency Public Information Portal. The goal of the portal is to "turn data into useful information for our customers" and to "create tools for getting answers to some of the questions we get most often". The VTransparency Portal features different tools for viewing specific data. These tools include:

- Projects Map
- Road Conditions
- Plow Finder
- Weather Cams
- Maintenance Districts
- Crash Fatality Report
- Crash Query Tool
- Find a Project
- Daily Traffic
- Highway Closures
- Bridge Inspections
- Pavement Conditions
- Pavement Performance
- Maintenance Work
- Rail Asset Inventory
- Rail Bridge Inspections
- Rail Clearance
- Rail X-ing Inspections

The VTransparency Portal also links to the Vermont Open GeoData Portal. This provides GIS map layers related to the various tools for people interested in doing their own analysis of VTrans data. VTrans holds to the principle of making data available by default unless it is sensitive. The agency values transparency with the public and welcomes feedback on the tools they've developed. The VTransparency Portal can be accessed at https://vtrans.vermont.gov/vtransparency

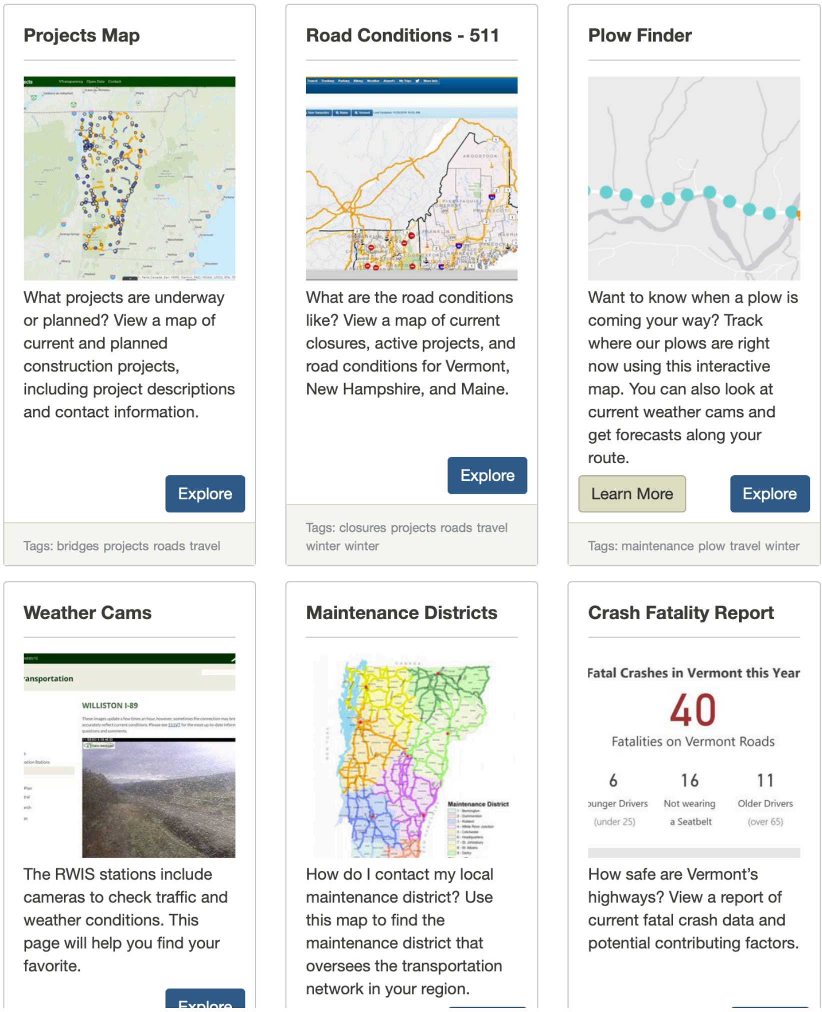


Table 7.5 Data Sharing Options

Data Sharing Option	Most appropriate for...	Considerations
On request	Internal or external data users	Use for uncommon, specialized requests requiring moderate to extensive effort to fulfill or where there is high potential for information misinterpretation or mis-use For common information needs, use other methods to reduce staff time spent on fulfilling information requests.
Direct access to specialized asset management system (e.g. for pavement, bridges, culverts, etc.)	Asset and maintenance specialists in the central office and field offices	Helpful features include: ability to provide view-only privileges and ability to provide filtered views of information (e.g. restrict to a single district)
Direct access to enterprise asset management system (with information about multiple assets)	Agency staff Partner agency staff (e.g. MPOs, localities)	For partner agency access, ability to provide access outside of the agency firewall is needed.
Enterprise GIS with spatial open data portal	Internal or external data users	It is best to design separate maps geared to specific user types May want to separate internal and external portals or restrict some specialized maps for internal use.
General open data portal	Internal or external data users	Consider using available federal and state-level open data portals May want to separate internal and external portals or restrict some specialized maps for internal use.
Data feeds/data services/Automated Programming Interfaces (APIs)	Internal or external data users	Most suitable for real time data sets, data sets that are frequently updated, and complex data sets where flexible querying options are needed.
Data warehouse/data mart	Agency staff	Use to create a cleansed and standardized data source for reporting/business intelligence. Particularly helpful when historical/time series data is required, and direct access to data from source systems is problematic due to data quality, consistency or performance concerns. Tabular data within the Data Warehouse can be joined with spatial data, as needed, within the Enterprise GIS.
Data lake	Agency data analysts/data scientists	Use to provide access to a heterogeneous collection of data including "big data" and unstructured data for research, modeling and analysis.
Content management system	Agency staff and partners (e.g. contractors)	Use to provide access to a curated collection of content including engineering design drawings, asset maintenance manuals, contracts, etc.
Common data environment (CDE)	Agency staff and partners (e.g. contractors)	Use to provide a shared information repository for a construction project. CDEs typically include document management, collaboration and workflow features. CDE is one of the key elements of BIM practice defined by the UK's Construction Industry Council.

Preparing Data for Sharing, Reporting and Visualization

Establishing a standard process to prepare data for sharing, reporting and visualization can make sure that data is publication-ready: quality checked, tested and documented.

A standard data preparation process should be used before moving data to any official reporting source – whether it is a data warehouse, a geodatabase, or a file uploaded to an open data portal.

A data preparation process might use the following checklist:

- Is the data derived from a designated authoritative source system?
- Have data quality checks been applied?
- Has metadata for the data set been prepared, including explanation of the data source, date of last update?
- Is an individual or business unit identified for data users to contact for further information?
- Is an individual or business unit identified for reporting database or system managers to contact regarding any issues that arise?
- Has metadata for the data elements included been prepared (data dictionary)?
- Has the metadata been reviewed for completeness and quality?
- Has a data owner or steward signed off on the data publication?

Definition of Data-Driven Decision Making

Ohio DOT

"Data-driven decision making is an approach to business governance or operations which values decisions supported with verifiable data. The success of the data-driven approach is reliant upon the quality of the data gathered and the effectiveness of its analysis and interpretation"

Checklist

Preparing Data for Sharing, Reporting and Visualization

Establishing a standard process to prepare data for sharing, reporting and visualization can make sure that data is publication-ready: quality checked, tested and documented. A standard data preparation process should be used before moving data to any official reporting source – whether it is a data warehouse, a geodatabase, or a file uploaded to an open data portal.

- ☐ **Is the data derived from a designated authoritative source system?**
- ☐ **Have data quality checks been applied?**
- ☐ **Has metadata for the data set been prepared, including explanation of the data source, date of last update?**
- ☐ **Is an individual or business unit identified for data users to contact for further information?**
- ☐ **Is an individual or business unit identified for reporting database or system managers to contact regarding any issues that arise?**
- ☐ **Has metadata for the data elements included been prepared (data dictionary)?**
- ☐ **Has the metadata been reviewed for completeness and quality?**
- ☐ **Has a data owner or steward signed off on the data publication?**

Section 7.4

Data Governance and Management

This section provides an overview of data governance and management practices that are essential for achieving data quality, consistency and integration. These practices are applicable to all kinds of agency data, and are best implemented at the agency-wide level. After introducing general concepts and principles, the section highlights specific governance and management applications for TAM. It concludes with a synthesis of available tools for assessing data governance and management maturity levels.

This section has three parts:

1. **Fundamental Concepts and Principles**. Provides a basic overview of data management, data governance, and data stewardship.
2. **Data Governance Practices Supporting TAM**. Provides information on the key decision points that need to be governed and key considerations in setting up a data governance process.
3. **Assessing Data Governance and Management Maturity**. Provides information on assessment tools and models available for agencies to determine their level of maturity with regard to data and the ways they can improve.

Fundamental Concepts and Principles

Data governance and management practices are essential for achieving reliable, consistent, integrated and accessible data that is of value for decision-making. Several definitions, concepts and principles are important to understand before embarking on a data governance initiative.

Data governance and data management are interrelated but distinct practices.

Data management includes activities such as data quality management, data documentation, metadata management, security and access controls, data integration, and data archiving.

Data governance is a policy making and oversight function for data management. Implementing data governance involves forming and chartering decision making bodies, defining roles and responsibilities, establishing policies that set expectations for behavior, and setting up standard processes for things like approving data standards, resolving data issues, and acquiring new types of data. Data governance is generally implemented in a hierarchical fashion, with an executive body at the top, a data council or board in the middle, and several more focused groups oriented around specific systems, business processes, organizational units or functions.

Data stewardship is closely related to data management and governance. It refers to established responsibilities and accountabilities for managing data. In general parlance, a steward is someone who is entrusted with the responsibility for taking care of someone else's property. Similarly, a data steward is someone who takes care of data on behalf of their agency. Different types of stewardship roles can be defined and formalized within an agency data governance policy. Data stewardship can be viewed as the way to operationalize data governance policies, processes and standards.

Data governance can be implemented to:

- Improve quality and consistency of data
- Ensure coordination across different business units
- Maximize efficiency in data collection and management processes
- Enable data integration and shared solutions to make the most of available IT resources
- Ensure there is a solid business case for new data collection
- Ensure that data will be maintained once it is collected

Agencies may be motivated to establish a formal data governance function as they try to move from a siloed approach to collecting and managing data to one that is more coordinated and centralized.

For example, implementing a reporting system that takes data from multiple sources within the agency creates the need for standardization, documentation, and agreed-upon update cycles. It is important to get agreement on standard data definitions, formats and code lists from different business units to achieve consistency. It is also important to clarify who is responsible for fixing errors and the process for error correction in the even that errors occur.

Data governance is a means to an end. It is important to clearly define and communicate why an agency needs to strengthen data governance: what is happening now that the agency may want to avoid (such as data duplication)? What is not happening now that the agency may want to achieve (such as standardized data)? The effort involved in putting data governance in place should not be underestimated, since it involves changes in how decisions are made and changes in behavior. A full scale agency data governance model can take years to mature. However, data governance can be rolled out incrementally to focus on short term objectives. It is a good idea to adopt a set of principles to provide the foundation for data governance policies and practices. The AASHTO Data Principles (see callout box) can be used as a model.

AASHTO Data Principles

1. **VALUABLE.** Data is an asset—Data is a core business asset that has value and is managed accordingly.
2. **AVAILABLE.** Data is open, accessible, transparent and shared—Access to data is critical to performing duties and functions, data must be open and usable for diverse applications and open to all.
3. **RELIABLE.** Data quality and extent is fit for a variety of applications—Data quality is acceptable and meets the needs for which it is intended.
4. **AUTHORIZED.** Data is secure and compliant with regulations—Data is trustworthy and is safeguarded from unauthorized access, whether malicious, fraudulent or erroneous
5. **CLEAR.** There is a common vocabulary and data definition—Data dictionaries are developed and meta data established to maximize consistency and transparency of data across systems.
6. **EFFICIENT.** Data is not duplicated—Data is collected once and used many times for many purposes.
7. **ACCOUNTABLE.** Decisions maximize the benefit of data—Timely, relevant, high quality data are essential to maximize the utility of data for decision making.

Practice Example

Florida DOT • Enterprise Information Management

Florida Department of Transportation (FDOT) launched a statewide initiative to better manage and integrate agency data. This effort combines the resources, goals, and objectives of Florida's Technology and Operation Divisions into the initiative known as ROADS, which stands for:

R—Reliable, accurate, authoritative, accessible data

O—Organized data that produces actionable information

A—Accurate governance-produced data

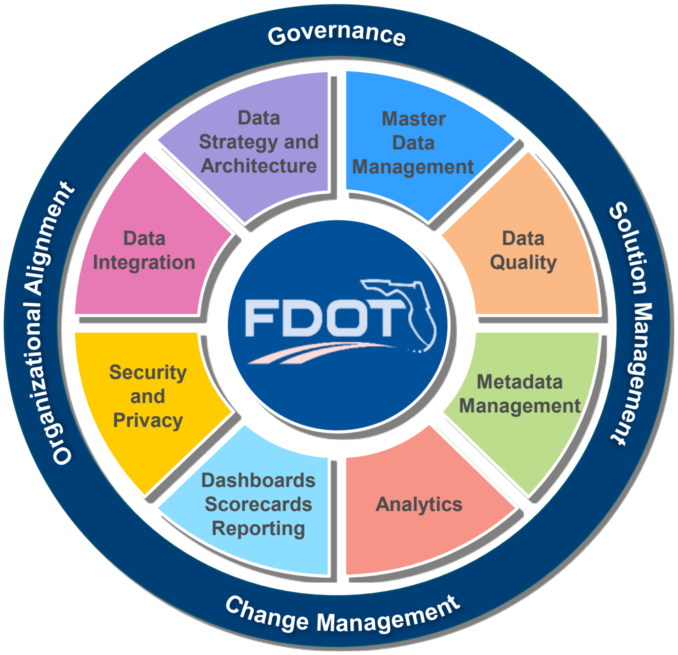
D—Data and technology integration

S—Shared agency data to perform cross-functional analysis

The agency has created processes, procedures, and guidelines so that all data (financial, safety, project, program, assets, etc.) are organized and accessible. Florida's steering committee, known as RET (ROADS Executive Team), is led by the agency's Chief of Transportation Technology and Civil Integrated Management Officer. The committee, which includes district secretaries, financial and planning executives, and operational directors, is charged with governance leadership and instituting processes that will change the culture of the agency by converting data to knowledge.

ROADS is being implemented incrementally, through a series of 6-month initiatives. One initiative related to asset management is to standardize inventory attributes for 120 different classes of infrastructure assets and the agency's approximately 170 enterprise software applications. Part of this effort is to determine specific authoritative source data to include in a new data warehouse. The data warehouse will provide a single authoritative site for sharing the accurate data.

Through the ROADS initiatives, Florida DOT has created a strategic direction for data integration covering data stewards, division responsibilities, asset inventory, business system integration, and an implementation roadmap. By coordinating its efforts, the agency is able to maximize the value of its data while streamlining processes for data collection, management, and dissemination.



Florida DOT Enterprise Information Management
Source: Florida DOT. 2019

TIP **Data itself should be viewed as an asset to be managed.**

Data Governance Practices Supporting TAM

Data governance practices can be implemented to support development of a valuable, reliable base of integrated information for TAM decision making.

A first step in data governance is to identify key decision points to be governed. These may include:

- Adopting common data definitions or standard code lists
- Adopting location referencing standards
- Adopting standard tools for field data collection
- Collecting new asset data to be included within an integrated asset management system
- Archiving or deleting existing data
- Modifying data elements for an existing TAM data source
- Adding new data layers to an enterprise GIS repository
- Adding new data marts to a data warehouse
- Adding new reports or controls to a BI environment
- Responding to an external request for data

It is best to take an incremental approach to setting up governance processes, starting with a few high impact areas that are aligned with what the agency is trying to achieve. For each of the selected decisions to be governed, think both about the criteria or guidelines to be followed as well as all the people who should be consulted or involved in making the decision.

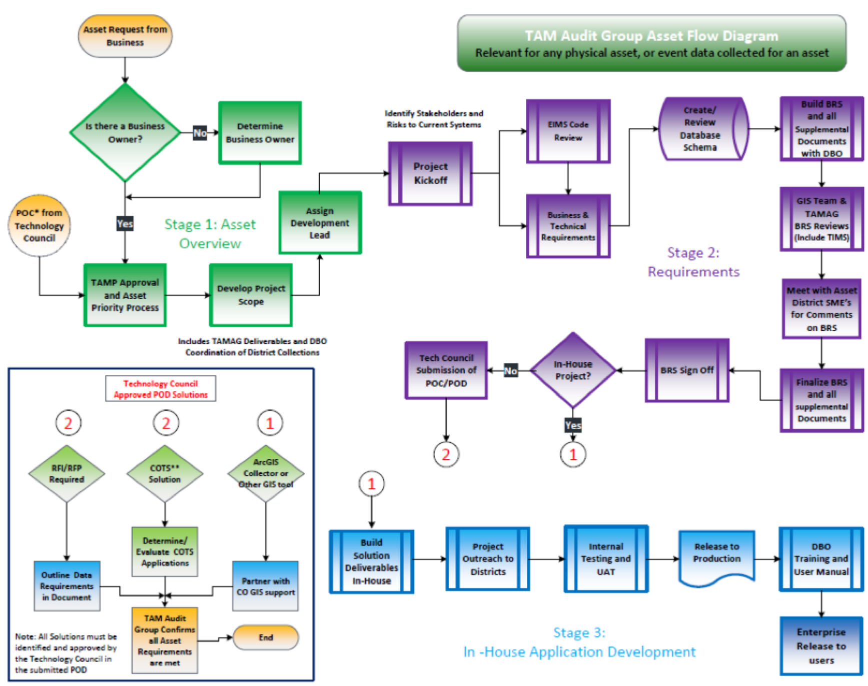
- **Criteria and Guidelines:** Developing guidelines for key decisions is a good way to institutionalize practices that reflect the agency's goals for data. For example, some agencies have established "readiness checklists" that need to be completed before data can be added to an enterprise

Practice Example
Process for Adding New Asset Data

Ohio DOT

Ohio DOT has established a standard process for adding a new asset to their inventory. As illustrated in the flowchart below, the process has three stages – (1) Asset Overview, where the request is submitted, evaluated, and approved, (2) Requirements, in which business and technical requirements for collecting and managing the new data are documented, and (3) Application Development, where the technology solution is developed either in-house (using standard tools), via contract (for custom development) or through acquisition of a commercial off-the-shelf (COTS) package.

As part of the TAM Audit Group workflow shown in the figure, ODOT has introduced over 693,000 active ancillary assets into their inventory.



Ohio DOT TAM Audit Group Workflow Diagram
Source: Ohio DOT. 2019

TIP Data governance practices should involve stakeholders responsible for collecting and analyzing the data, as well as those who will be using the data in decision making.

repository. These ensure (among other things) that a data owner or point of contact has been identified, that necessary metadata is provided, that a refresh cycle has been specified, and that the authoritative source system of record has been identified.

- **Decision Making Process:** Consider who should be involved in each of these decisions – who is responsible for making technical recommendations, who should be consulted, who has approval authority, and who needs to be informed about the decision. Define a process for resolving issues and conflicts; and a process for granting exceptions to established standards.

Agency data governance bodies can be responsible for adopting both guidelines and process flows impacting decisions that impact multiple business functions. If there are no existing governance bodies or if decisions to be governed are specific to TAM, a separate TAM data governance group can be established.

Keep in mind that the function of governance bodies is to make decisions. Use technical advisory groups, working groups or communities of interest to do the collaborative work required to develop standards or make recommendations about changes to data and systems.

Assessing Data Management and Governance Maturity

Data management and governance implementation can be viewed as a long term process of maturation. Several models and assessment tools are available to help agencies identify their current state, set goals for where they want to be, and create plans for moving up the maturity scale.

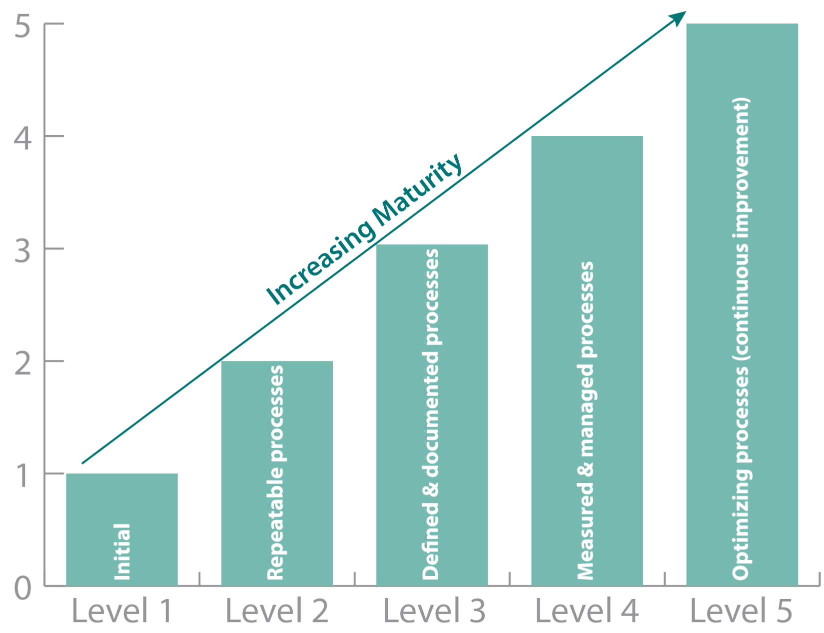
There are several different assessment tools tailored to DOT data programs that can be used or adapted as needed. In addition, several DOTs have created their own tools. Most of these tools are based on a maturity model.

A typical maturity model could include the following levels:

- Level 1-Initial
- Level 2-Repeatable processes
- Level 3-Defined and documented processes
- Level 4-Measured and managed processes
- Level 5-Optimizing processes (continuous improvement)

For TAM information and systems, maturity levels can be assigned to different aspects of

Figure 7.2 Example Maturity Model

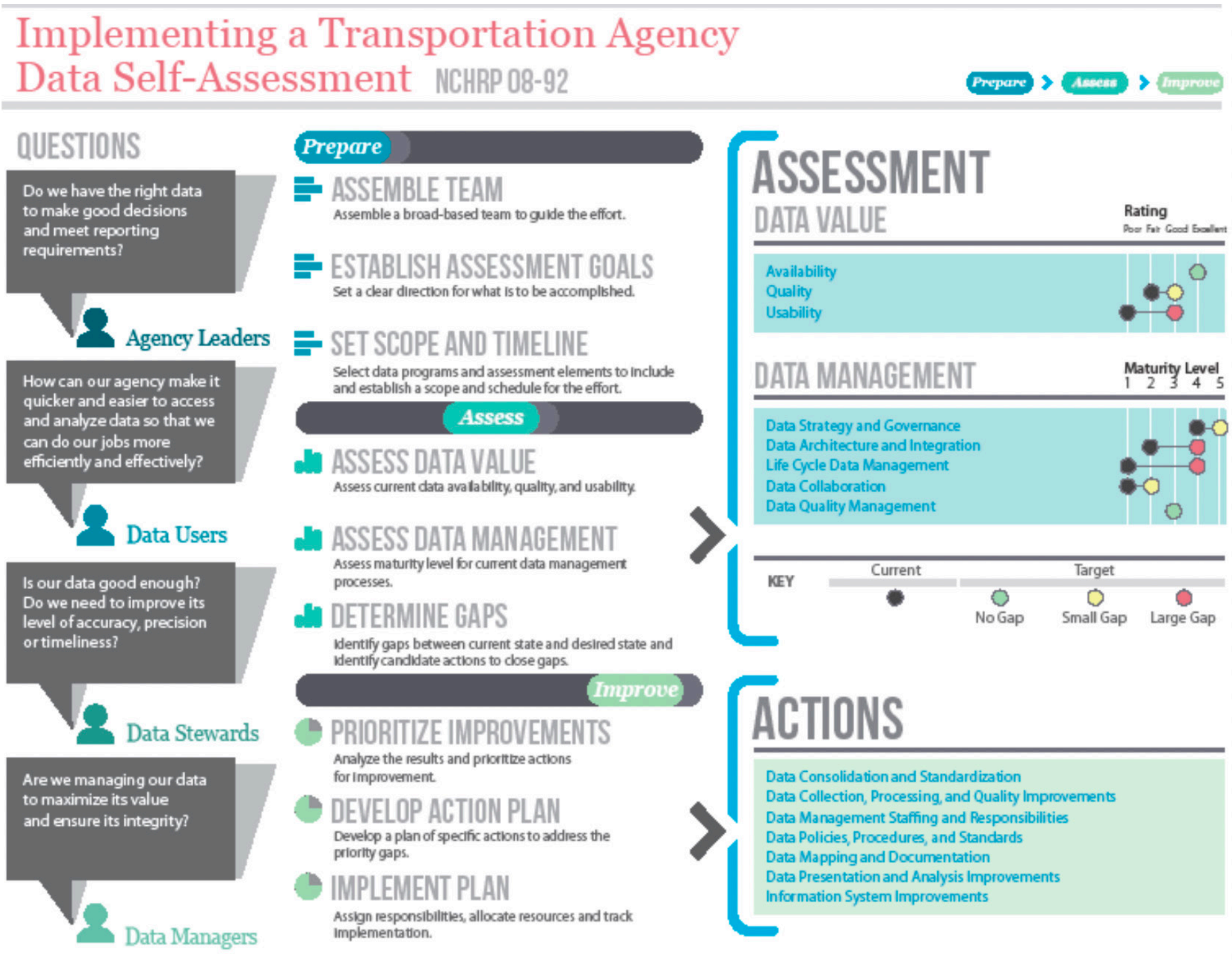


TIP Use a maturity model to identify gaps, prioritize initiatives and track progress over time.

data management and governance. Assessments can also be conducted at different levels of the organization – from the agency-wide level, to the level of individual information systems (or even data elements).

Table 7.6 shows the data management and information system-related assessment elements from the TAM Gap Analysis Tool, developed under NCHRP Project 08-90. Figure 7.3 illustrates the data assessment guidance created under NCHRP 08-92. This process is suitable for application either at the agency-wide level, for an individual data program, or for a business process. It goes into greater depth than the TAM Gap Analysis Tool.

Figure 7.3 Folio Describing the Transportation Agency Data Self-Assessment Process



Source: Transportation Research Board. 2015. *Implementing a Transportation Agency Data Self-Assessment*

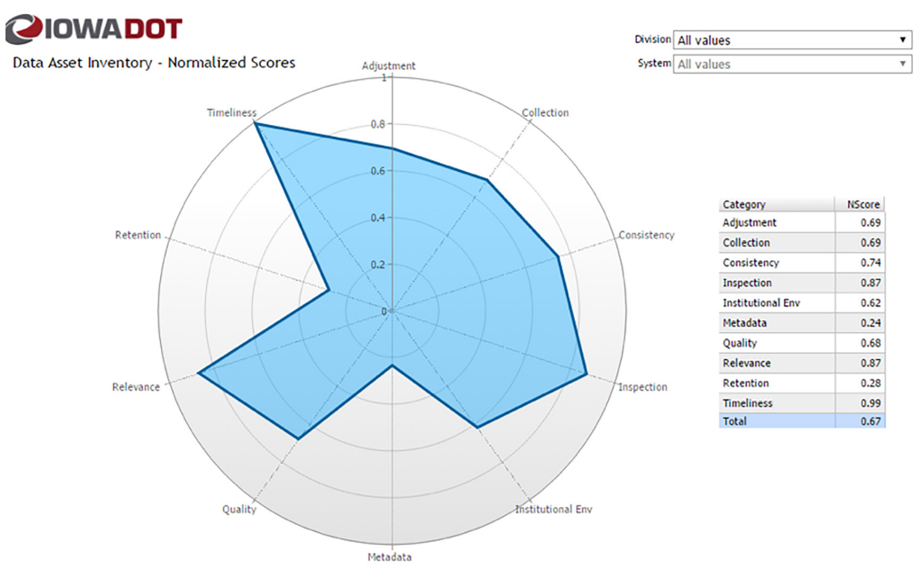
Relevant Resources

- NCHRP Synthesis Report 508- Data Management and Governance Practices - http://www.trb.org/Publications/Blurbs/176005.aspx
- NCHRP Report 814, Data to Support Transportation Agency Business Needs: A Self-Assessment Guide
- Cambridge Systematics et. al., Target-setting methods and data management to support performance-based resource allocation by transportation agencies: volume I: research report: volume II; guide for target-setting and data management. No. 666. Transportation Research Board of the National Academies, Washington, D.C (2010) 133 pp. - http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_666.pdf
- The Data Management Association Data Management Body of Knowledge version 2 - http://www.dama.org/content/body-knowledge
- National Association of State Chief Information Officers Data Governance Articles
  - http://www.nascio.org/publications/documents/NASCIO-DataGovernance-Part1.pdf
  - http://www.nascio.org/publications/documents/nascio-datagovernanceptii.pdf
  - http://www.nascio.org/publications/documents/nascio-datagovernanceptiii.pdf
- Data Governance Institute – http://www.DataGovernance.com/
- TAM Gap Analysis Tool - https://www.tam-portal.com/resource/aashto-transportation-asset-management-gap-analysis-tool-users-guide/

Practice Example
Data Assessment

Iowa DOT

Iowa DOT conducted a detailed data maturity assessment for over 180 data systems. Assessments were based on a standardized questionnaire administered to data stewards and custodians. The questions covered data quality, availability of metadata, whether a data retention plan was in place, the degree to which data collection was automated, and several other factors. Charts were produced showing maturity scores for each system, with roll-ups at the division level. This tool helps the agency track their progress over time and identify specific data improvements to pursue.



Sample Data Assessment Summary Radar Chart
Source: Iowa DOT. 2019

Table 7.6 TAM Gap Analysis Tool Assessment Elements

Element	Sub-element	Sample Assessment Criteria
Data Management	Asset Inventory	• Complete, accurate, current inventory data • Critical asset components identified • Asset tiers identified to facilitate prioritization • Location-based data collection practices (e.g. GPS) • Appropriate mix of data collection technology • Inventory level of detail considers maintenance costs, accuracy, and asset criticality
	Asset Condition and Performance	• Periodic/regular collection of condition and performance data • Adequate level of coverage to ensure objectivity, consistency and repeatability • Assessments by knowledgeable personnel • Ability to monitor operational status of assets • Monitoring of public perceptions
	Data Governance	• Oversight and approval authority for all data elements • Single authoritative sources for shared data entities • Data stewardship roles and responsibilities • Data standards • Central metadata repository • Business rules for add/update/delete • Efforts to reduce redundancy • Quality assessment and improvement
Information Systems	System Technology and Integration	• Updated asset management systems • Integrated to provide consistent information across assets • Serving multiple users and uses • Established requirements and standards to guide future development • Common geographic referencing • Procedure to manage changes in referencing • Common map-based interface
	Decision-Support Tools	• Pavement management system • Bridge management system • Maintenance management system • Capital-maintenance tradeoff capabilities
	System Features	• Life cycle analysis • Cost data • Performance data – impacts of maintenance and preservation • Cost and performance prediction • Future demand prediction • Regular review of treatment intervention strategies • Benefit/cost or optimization analysis

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
Information and Systems	Emerging	• Agency information systems are unintegrated, however the current portfolio of systems are well mapped, and an improvement plan is in progress to improve integration toward a clearly defined future state that is suited to agency requirements.
	Strengthening	• Agency information systems are partially integrated, interconnected and a plan is being implemented to create a system that is suited to agency requirements.
	Advanced	• Agency information systems are fully integrated. Systems supporting inventory management, data warehouses and statistics, inspections and condition assessments, maintenance management, performance modeling, analytics, forecasting and financial systems are interconnected and are suited to agency requirements.
Collecting Asset Data	Emerging	• Collection occurs periodically and data is maintained, current and accurate..
	Strengthening	• Data collection strategies are targeted to agency decision-making requirements. • Collection occurs periodically and data is maintained, current and accurate.
	Advanced	• Data collection strategies are targeted to agency decision-making requirements, and collection resources add value. • Collection occurs periodically and data is maintained, current and accurate.
Asset Data Sharing, Reporting, and Visualization	Emerging	• Information is available to most stakeholders and allow for improving decisions over time. • Data and analysis presentation is improving with a plan for consistency across the agency..
	Strengthening	• Information is available to most stakeholders and allow for informed, supported decisions • Data and analysis presentation is improving and is targeted to key decision-makers, and consistent across the agency.
	Advanced	• Information is available to all stakeholders and allow for informed, supported decisions • Data and analysis presentation is well crafted, easy to understand for the targeted audience, and consistent across the agency.
Data Governance and Management	Emerging	• Data governance and management practices are being established with a gap assessment identifying an improvement strategy over time.
	Strengthening	• Data governance and management practices well established and support continuous improvement in data systems.
	Advanced	• Data governance and management practices well established and support reliable, consistent, integrated and accessible data systems • Governance frameworks are reviewed periodically to ensure it evolves with agency requirements

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